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THE SIGNIFICANCE OF THE BACTERIAL FLORA ON WHEAT SEED IN INOCULATION STUDIES WITH HELMINTHOSPORIUM SATIVUM[1]

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INTRODUCTION

In a recent paper, Simmonds (1) brought out the importance of antibiotic organisms in tests of resistance to common root rot in cereals. His studies laid the basis for a simple technique for measuring resistance to *Helminthosporium sativum* P. K. and B. in wheat seedlings. The present paper supplies further data in support of his interpretations. It also records studies on the effect of removing and re-applying bacteria to wheat seed. Some attention is given to the effects, when seed is treated, of the disinfectants on seedlings and their effectiveness in eliminating bacteria from seed. Pertinent literature has been reviewed by Simmonds (1).

EXPERIMENTAL METHODS

In most of the laboratory tests, seedlings were grown in Petri dishes on moist filter paper. Inoculations, unless otherwise indicated, were made by application of a drop of conidial suspension of *H. sativum* to each seed. Glass rods of 3 mm. diameter, and rounded at the ends, were used to apply the suspension. Treatment methods, both as applied to seed disinfectants and antibiotic agents, have varied; they will be described as the need arises. Formalin (commercial preparation of formaldehyde, 37 per cent, in water) was used in many of the tests; wherever it was used, the seed was thoroughly washed afterwards in sterile water. Examination of the seedlings was carried out usually after four days of incubation at 24° C. Plants were placed in the following classes: free from lesions, and with slight, moderate, or severe lesions. Disease ratings were computed on a percentage basis, with values of 0, 1, 5, and 10 assigned to these classes, respectively.

SURFACE DISINFECTION OF SEED IN INOCULATION STUDIES

Simmonds reported (1) that higher disease ratings resulted from inoculation with *H. sativum* after wheat seed was treated with formalin and washed with sterile water than when not treated. Increases in lesions were ascribed to removal of bacteria antagonistic to *H. sativum*. It is

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well known that formalin-treated seed will sometimes show injury, as evidenced by lowered vigour and increased susceptibility to disease. The increased lesioning (1) might be attributed to the formalin injury rendering the seedling more liable to infection by *H. sativum*. Therefore, information was necessary to decide this point since, if the observed increases in disease following seed disinfection were due simply to seedling injury, the role of bacteria would be in doubt. A number of tests were conducted, some of which are reported below. They provide data on other aspects of the problem than the one relating to removal of bacterial seed flora.

At the outset, comparisons between formalin treated and hot-water treated grain were made. The seeds were inoculated after treatment and disease ratings were obtained. In general, when the surface flora was reduced with hot water, the disease ratings were comparable to those obtained when formalin was used. A refinement of technique was based on the premise that, if hot water was used to remove the surface bacteria, subsequent treatment with formalin should not cause any further increase in disease, provided the role of the seed treatment was simply reduction or elimination of the bacterial flora. Accordingly, a number of tests were conducted, of which one soil test and two Petri-dish tests comparing these treatments are reported.

Soil Test

Sixteen pots were filled with soil and eight of them were steam sterilized. Seed of the variety Thatcher was soaked in water at 52° C. for ten minutes. Half of this seed was then further treated for ten minutes with formalin and finally washed in sterile water. The formalin solution was made up of one part formalin in 320 parts of water. The various lots of seed were inoculated by dipping them in a conidial suspension of *H. sativum*. One-half of the pots were planted with hot-water treated seed and one-half with seed which had received both treatments. Fifty seeds were placed in each pot. After four weeks in the greenhouse at a temperature of about 70° F., the seedlings were harvested and disease ratings obtained. These are shown in Table 1.

TABLE 1.—THE INFLUENCE OF HOT WATER AND FORMALIN TREATMENTS OF THE SEED ON DISEASE RATINGS OF WHEAT SEEDLINGS INOCULATED WITH *H. sativum* IN SOIL

Treatments	Unsterilized soil	Sterilized soil
Hot water	59	68
Hot water + formalin	64	65

This test provides evidence that formalin did not induce an increase in lesioning above that ascribable to hot water alone. The differences between the two treatments in either sterilized or unsterilized soil do not approach significance.

Petri-dish Tests

Duplicate Petri-dish tests were made to further elucidate this point. Four factor factorial designs were used. Thatcher and Reward were the varieties selected and portions of each were treated as follows:

(1) Hot water, 10 minutes at 48° C. after a 20 minute pre-soak in cool water.

(2) Formalin, 20 minutes in solution of 1 : 400 concentration after a 10 minute pre-soak.

(3) Combined treatment in which formalin followed hot water.

(4) No treatment.

In addition to an inoculated series, a duplicate uninoculated series was included to determine whether any of the treatments caused delay in germination or other abnormalities. Scrutiny of the uninoculated plates after four days' development showed no apparent differences in germination and practically no lesioning; therefore, only the results of the inoculated series are reported. The disease ratings in percentage are shown in Table 2.

TABLE 2.—DISEASE RATINGS IN A PETRI-DISH TEST WITH THATCHER AND REWARD TREATED WITH HOT WATER, FORMALIN, AND THE TWO COMBINED, FOLLOWED BY INOCULATION WITH *H. sativum*

Variety	Test	Untreated	Hot water	Formalin	Hot water and formalin
Thatcher	1	29	63	59	69
	2	15	49	42	62
Reward	1	90	89	94	95
	2	91	83	95	88
Treatment means		56	71	72	78

Table 2 shows no appreciable difference in disease rating between hot water treated and formalin treated seed, thus confirming preliminary results. Furthermore, in determining the most suitable schedule to follow in formalin and hot water treatments, treated but uninoculated seeds were placed on potato dextrose agar and examined after a day or two for bacterial colonies. It appeared that treatment with water at 48° C. for 10 minutes was about as effective as formalin 1 : 400 for 20 minutes in reducing the surface flora of the seeds. Neither treatment sterilized the seed surface completely. Thatcher showed a slightly higher disease rating in the combined treatment than in either of the treatments singly, which result may have been due to more complete elimination of surface inhabiting bacteria. Reward was much more severely diseased than Thatcher. This finding is in line with numerous previous tests.

In Thatcher, the wide difference in disease rating between treated and untreated seed reflects the effect of the normal seed flora on *H. sativum*. Fairly wide differences have almost always been observed with Thatcher

and with most other varieties and lines of wheat. These differences may be further widened by incubation of the seed prior to inoculation, to increase the bacterial flora, or by bacterization.

For some reason, the Reward seedlings in this test and other Reward samples as well have not had much protection from their surface flora. Further work is required to determine whether the difference between Reward and other varieties is in type or relative abundance of bacteria carried. Numerous factors may influence abundance and the type of flora which a given variety will support.

The foregoing data appear to provide good evidence that the effect of formalin in increasing the disease incidence is due simply to partial elimination of the bacterial flora from the seed surface and not to chemical injury.

BACTERIZATION IN INOCULATION STUDIES

Another approach to the problem of whether formalin caused disease increases through injury is based on re-application of a bacterial flora to formalin treated seed. Two laboratory tests were carried on in Petri dishes and two greenhouse tests in sterile and two in unsterile soil.

Petri-dish Tests

Separate 40 gm. lots of Thatcher and of Reward seed were moistened with water equal to 50 per cent of their weight. They were incubated for 20 hours at room temperature. Suspensions of the surface organisms were made by adding 10 cc. of water to each lot, then shaking and pouring off the liquid. These suspensions were applied, both singly and combined, to the untreated and the formalin treated seed of each variety. Where the two suspensions were combined on the same seed sample, they were mixed in equal amounts and the seed dipped in them. Where one suspension was applied, it was diluted with an equal quantity of water. The result was that approximately twice as many bacteria were added to the seed in the combined as in the single treatment. The usual inoculation with *H. sativum* was carried out and the disease ratings were taken after a four-day period. Data from the uninoculated series are not included since they did not indicate abnormalities due to the various treatments. Table 3 gives the averaged data from two Petri-dish tests.

TABLE 3.—EFFECT OF BACTERIZATION ON DISEASE RATINGS IN SEEDLINGS OF THATCHER AND REWARD INOCULATED WITH *H. sativum*

Treatments*	Thatcher		Reward	
	No formalin	Formalin	No formalin	Formalin
o	33	60	80	87
r	1	5	13	22
t	6	31	12	50
rt	1	2	17	22

* r – Suspension of organisms from incubated Reward seed.
t – Suspension of organisms from incubated Thatcher seed.

The disease ratings of Table 3 have been summarized to show significant main effects and first order interactions. These are shown in the following 2 × 2 tables.

TABLE 4.—EFFECT OF SEED TREATMENT WITH FORMALIN ON DISEASE RATINGS IN REWARD AND THATCHER

	No formalin	Formalin	Means*
Reward	30	45	37
Thatcher	10	24	17
Means*	20	34	27

* Main effects exceed the 1 per cent level of significance.

TABLE 5.—EFFECT ON DISEASE RATINGS OF APPLYING BACTERIA OBTAINED FROM REWARD AND THATCHER TO THESE VARIETIES

	No Reward organisms	Reward organisms	Means*
No Thatcher organisms	65	10	37
Thatcher organisms	25	10	17
Means*	45	10	27

* Main effects exceed the 1 per cent level of significance, as also does their interaction.

The usual wide difference between Reward and Thatcher in disease rating is apparent in these tests. The marked increase in disease following treatment of Thatcher with formalin constitutes evidence of a natural flora antibioltic to *H. sativum*. Reward on the other hand derived very little protection from its normal seed flora (Tables 2 and 3). Bacterization, however, decreased markedly the disease rating in Reward. It is interesting, furthermore, that the bacteria derived from the incubated Reward were as effective as those obtained from Thatcher (Table 5), yet the same seed sample from which these were obtained, when inoculated directly, was not afforded any protection. This result suggests that the bacterial flora on this sample of Reward was similar to that on Thatcher in type but so low in numbers as to require increasing before it could be effective.

Sterile-soil Tests

Two greenhouse tests in sterilized soil included treatments similar to those carried on in Petri dishes, as described above. Water suspensions of organisms obtained by incubating moistened Reward and Marquis seed were used in bacterization of the seed. A factorial design with four factors at two levels each was used in both experiments. The factors were, respectively: (1) variety of host plant, Thatcher and Reward; (2) bacterization with Reward organisms and no Reward organisms; (3) bacterization with Thatcher organisms and no Thatcher organisms; and (4) formalin treatment of the seed and no such treatment. All seed was inoculated with *H. sativum* after the above treatments were made. The third order interaction was confounded. Each test consisted of 32 five-inch pots, and 50 seeds were planted in each. After ten days of development at a temperature of about 70° F., the seedlings were removed from the soil and were

classified as to degree of lesioning. The significant main and interaction effects are shown in Tables 6 and 7. The disease ratings are averaged over two varieties, Thatcher and Reward.

TABLE 6.—DISEASE RATINGS, IN AN INOCULATION TEST WITH *H. sativum* IN STERILE SOIL, SHOWING THE INFLUENCE OF BACTERIZATION WITH THATCHER AND REWARD ORGANISMS AND THEIR INTERACTIONS

	No Reward organisms	Reward organisms	Means*
No Thatcher organisms	63	39	51
Thatcher organisms	43	39	41
Means*	53	39	46

* Necessary difference for significance in means at the 1 per cent level is 9.

Bacterization of the seed with organisms from both Reward and Thatcher, singly and in combination, reduced significantly the disease ratings on wheat seedlings caused by *H. sativum*. There was, however, a highly significant interaction between the two treatments, indicating that their effects on the disease ratings were not additive.

TABLE 7.—DISEASE RATINGS SHOWING THE EFFECT OF FORMALIN TREATMENT OF THE SEED AND THE INTERACTION BETWEEN FORMALIN SEED TREATMENT AND BACTERIZATION OF THE SEED WITH THATCHER ORGANISMS

	No Thatcher organisms	Thatcher organisms	Means*
No formalin	67	40	53
Formalin	76	48	62
Means*	71	44	57

* Necessary difference for significance in means at the 5 per cent level is 9; at the 1 per cent level is 12.

It is evident from Table 7 that bacterization was very effective in reducing the incidence of disease, while formalin treatment increased the disease rating significantly. The seedlings showing the lowest amount of disease were those which had not been treated with formalin but had been bacterized. The ones in which the seed had been treated with formalin and not bacterized were the most severely diseased.

Unsterile-soil Tests

Two tests similar in general detail to those reported above in sterile soil were carried out in unsterile soil in a bed in the greenhouse. Reward and Thatcher seed was used, one-half of each sample being treated with formalin and then washed repeatedly with sterile water. The treated and untreated portions of each sample were bacterized with (*a*) a bacterial suspension obtained by rinsing the organisms off a sample of Marquis wheat which had been incubated for 24 hours, and (*b*) a suspension of a

bacterial culture obtained from wheat seed and increased on potato dextrose agar. In addition to bacterization with each suspension singly, the two were combined on the appropriate seed samples. The test was set up as a 2^4 factorial experiment with the third order interaction confounded. Disease ratings were obtained after ten days of development in the greenhouse at around 70° F. The results from the two tests conducted at different times were quite comparable so that the results of one test only are reported here.

The usual wide differences between Reward and Thatcher as to susceptibility were observed. However, this test is reported mainly to show the effect of bacterization of seed on disease rating in an inoculation test in unsterile soil. The data are presented in Table 8 to show main and interaction effects of the two bacterial suspensions on disease ratings, average of Thatcher and Reward.

TABLE 8.—MAIN AND INTERACTION EFFECTS OF BACTERIAL SUSPENSIONS ON DISEASE RATING IN WHEAT

	No bacteria	Bacteria	Means
No treatment	31	9	20
Marquis organisms	11	5	8
Means	21	7	14

Table 8 shows a disease rating of 31 in the absence of bacterization. Each of the suspensions used in bacterization gave good decreases in disease ratings. The combined suspensions likewise gave good control though it appears their effects were not additive; either one singly was nearly as effective as the two together, and this in spite of the fact that there were approximately twice as many bacteria applied to the seed in the combined as in the single suspensions.

ARTIFICIAL WEATHERING OF MATURE WHEAT PLANTS

Perhaps the most direct evidence pointing to the effect of surface-borne bacteria in lessening the disease caused by *H. sativum* in inoculation tests with wheat and also the effect of formalin in increasing the disease rating was derived from the following test. Thirty-six pots of Thatcher wheat were grown to maturity in the greenhouse. Care was taken to avoid wetting the heads at any time and in general the air humidity was very low. A week or two after the grain was ripe the pots were divided into four groups and three of these were subjected to periods of one, two, and three days, respectively, of humid conditions. This was done by placing the plants in a moist chamber equipped with a fog nozzle which was allowed to operate intermittently. The fourth group was left untreated. A month later, 200 seeds were taken at random from each group of plants and one-half of them were treated with formalin. The seeds, treated and untreated, were then set up in a Petri-dish test and inoculated with *H. sativum*. Disease ratings were taken after four days. This test was repeated three months later with seed freshly harvested from the same

sources as the previous test. In the interim, the heads had been stored in envelopes at room temperature. The data from the two tests were analysed together. The disease ratings, averaged over the two tests, are shown in Table 9.

TABLE 9.—INOCULATION TEST WITH *H. sativum* SHOWING DISEASE RATINGS OF SEEDLINGS FROM GREENHOUSE GROWN THATCHER WHEAT, PORTIONS OF WHICH HAD BEEN EXPOSED TO HUMID CONDITIONS FOR VARYING PERIODS

Days of weathering	No formalin	Formalin
0	69	63
1	59	71
2	67	77
3	25	73

Necessary difference for significance at the 1 per cent level is 13.

In Table 9, the disease ratings of seedlings from seed which was not treated with formalin show that the 3-day period of weathering was very effective in reducing the amount of disease. The 1- and 2-day treatments did not have a highly significant effect. Formalin treatment destroyed the apparent resistance resulting from weathering. Previous work (Tables 5, 6, and 7) indicated that similar resistance was the result of an increased bacterial flora. Accordingly, 50 seeds from each of the 0-, 1-, and 3-day treatments were placed in test tubes and covered with sterile water. After five or six hours, the liquid in the tube containing the seed weathered for three days was turbid, while the other two were clear. Smears showed the turbidity to be due to bacteria. Furthermore, dry seeds of each treatment were placed on potato dextrose agar. After 24 hours, vigorous bacterial colonies had developed from every seed of the 3-day treatment, and only tiny colonies from a few seeds of the other treatments. The test demonstrates the role of bacteria in resistance of wheat seedlings to *H. sativum* and also that the effect of formalin is simply the elimination of bacteria.

DISCUSSION

Generally speaking, in inoculation tests of wheat with *H. sativum*, the results of formalin treatment and of bacterization of the seed followed the same trend in soil as in Petri dishes. There were differences, however, which were not unexpected. The role of seed disinfection in these tests was to eliminate the natural seed flora before inoculation with *H. sativum*, thus allowing the pathogen to develop without interference. In tests with unsterile soil, of course, the soil flora had an effect on the pathogen, so that the disease rating was not so high as was the case in sterilized soil or in Petri dishes. Several tests in unsterile soil did not show significantly higher disease on seedlings grown from formalin-treated than from untreated seed. On the other hand, in nearly all cases where the seedlings were grown in a more or less sterile medium, the disinfected seed produced

seedlings with a significantly higher incidence of disease. Numerous tests indicated that, with seed carrying a normal flora, there was a relationship between the effectiveness of seed treatment and the increase in disease rating of the treated over the untreated seed. Moreover, in a given variety, and with an efficient seed disinfectant, the difference in disease rating of seedlings from untreated and treated seed appeared to be an index of the relative abundance of the normal seed flora. Some seed samples gave a much increased rating following treatment. These, in all probability had an abundant natural flora. Conversely, seed produced in the greenhouse had a sparse bacterial population and, in inoculation tests, the seedlings from it had a high disease rating. In this case, treatment with formalin did not significantly change the disease rating. Artificial weathering of such seed increased the bacterial population greatly and, at the same time, rendered the seedlings much more resistant to *H. sativum*. Treatment of the weathered seed with formalin reduced its apparent resistance to *H. sativum* to the same level as before weathering.

While disinfection of the seed is essential to a seedling test of inherent resistance to *H. sativum*, there may be a place for increasing the abundance and effectiveness of the natural flora in protecting seedlings from infection. Thus, weathering which ordinarily occurs in the field probably has value. Simply moistening a seed lot and allowing it to incubate for a period of 16 hours or more will cause a great increase in its bacterial population. In turn, this results in a much reduced incidence of disease in inoculation tests. The initial seed flora has a bearing on how abundant it will be after a period of incubation. Bacterization of the seed with a suitable species of bacteria may be effective also in reducing the disease rating in inoculation tests. This procedure has given good results in inoculation tests with unsterilized as well as with sterilized soil in the greenhouse and in Petri-dish tests in the laboratory.

The treatment of wheat seed with formalin, as in the work reported in this paper, does not eliminate all the organisms present; however, it does reduce their numbers. Increasing the concentration of the fungicide or the length of treatment may result in injury to the seed and seedling. Further testing of materials is being continued in conjunction with the general problem and some of these appear promising.

SUMMARY

Treatment of seed with formalin prior to inoculation with *Helminthosporium sativum* as compared with untreated seed resulted in increased lesioning, particularly if the seedlings were grown in sterile soil or on other sterile media.

Numerous tests demonstrated that the cause of the increased disease under such conditions was the removal of surface organisms, particularly bacteria, which otherwise would have interfered with the development of the pathogen.

Different samples of wheat of a given variety may vary appreciably in the abundance of their surface flora. In inoculation tests to determine relative resistance to *H. sativum*, this variability of the seed flora results in corresponding variations in disease ratings. However, by proper surface disinfection of the seed prior to inoculation a truer measure of basic resistance of the variety is achieved. Likewise within any pure line more uniformity of results will be achieved.

The surface flora of wheat seed may be increased greatly by moistening the seed with water and allowing it to incubate for a period. Seedlings from seed so treated will show more resistance to *H. sativum* in inoculation tests, particularly in Petri dishes or in sterile soil, than those from unincubated seed. Similar results may be achieved by applying a suitable bacterial suspension to the seed prior to inoculation. In an inoculation test with *H. sativum* following bacterization of the seed, greenhouse trials indicated reduced disease in seedlings grown for ten days in unsterilized soil.

REFERENCE

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DIGESTIBILITY STUDIES WITH RUMINANTS

XIII. THE EFFECT OF THE PLANE OF NUTRITION ON THE DIGESTIBILITY OF LINSEED OIL MEAL[1]

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In previous publications (3, 4), the effect of the level of feeding on the digestibilities of rations of hay and of hay plus linseed oil meal have been reported. The hay was fed to steers at five levels from 2.5 to approximately 9 kilograms per day. The latter quantity depended upon the capacity of the animal. The coefficients of digestibility of the various nutrients of the hay were not affected by the level of feeding. In the hay-linseed oil meal rations the feeds were fed in equal proportions. The levels of feeding of the total ration were from 2 to approximately 10 kilograms. The latter amount depended upon the capacity of the animal. The average weight of all rations at the highest level was 9.58 kilograms. It was found that the digestibility of neither the protein nor of the fat was affected by the level of feeding. On the other hand, the carbohydrate fraction showed a decrease in digestibility as the level of feeding was increased. The magnitude was not very great, amounting over the whole range of feeding to a total of approximately 4 absolute per cent. This decrease was reflected in the digestibility of the dry matter and organic matter and in the total digestible nutrients. The most marked drop was found in the digestibility of the so-called crude fibre fraction.

In the above mentioned experiment the quantity of hay was increased equally with the oil meal. Since the plane of nutrition had no effect on the digestibility of hay alone any possible effects on the digestibility of the oil cake meal might have been partially masked. To investigate this, increasing quantities of oil meal were fed with a constant ration of hay. The digestibility of the nutrients of the oil meal were calculated from the different rations and the results are reported in this paper.

For the digestion trials six grade Shorthorn steers, numbered 11 to 16, inclusive, were used. They were $1\frac{1}{2}$ to 2 years old with a mean live weight during the experiment of 440 kilograms.

Six rations were fed, one of hay alone and five of various mixtures of hay and linseed oil meal. The hay was fed alone at a level of 6.5 to 7.0 kilograms per animal per day and in the mixtures at a level of 3.0 kilograms. The oil meal in the mixtures was fed at levels of 1, 2, 3, 4 and approximately 5 kilograms. The latter quantity depended upon the capacity of the animal.

The hay was largely timothy. Its botanical analysis is shown in Table 1.

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TABLE 1.—BOTANICAL ANALYSIS OF HAY

Herbage	Per cent
Timothy	65.7
Legumes (red and alsike clover, alfalfa)	33.4
Couch grass	0.7
Shepherd's purse, Canada thistle, Kentucky blue grass	Trace

The linseed oil meal was prepared by the screw-press method. The chemical composition of both feeds is given in Table 2.

TABLE 2.—CHEMICAL COMPOSITION OF FEEDING STUFFS (MEANS OF SIX VALUES)

Feeding stuff	Original dry matter	Chemical composition of dry matter				
		Ash	Protein*	Ether extract	Crude fibre	N-free extract
	%	%	%	%	%	%
Hay	86.87	5.63	9.64	1.16	39.14	44.44
Oil meal	92.69	5.45	35.66	7.56	9.47	41.86

* Protein factors (Jones (2))—Hay, 6.25 × N.
—Linseed oil meal, 5.83 × N.

The six rations were fed to the six animals through six periods in a randomized Latin square set-up. This is shown in the Appendix (Tables 6 and 7). Each period consisted of a preliminary sub-period of 16 days and a collection sub-period of 12 days. During the experiment mineral supplements of iodized salt, calcium, phosphorus, iron, copper, cobalt and manganese and vitamin supplements of A, D, E, thiamin, riboflavin and niacin were given.

RESULTS

The progress of the experiment was satisfactory with two exceptions. In periods 3 and 6 the animals receiving hay alone, namely, animal 14 in period 3 and animal 11 in period 6, had feed refusals and irregular consumption. These results were discarded. In addition, in period 2, with animal 16, the preliminary sub-period had to be lengthened thus reducing the collection sub-period to 10 days. With animal 11 in period 5 likewise the preliminary sub-period had to be lengthened, reducing the collection sub-period to 6 days. In both cases lengthening the sub-period was necessary because of adjustment of the ration during the first days of that sub-period. The remaining digestion trials progressed as scheduled.

In the Appendix (Tables 8, 9, 10 and 11), the coefficients of digestibility of the different nutrients in the rations, TDN in the dry matter of these rations and the data for the dry matter and nitrogen tabulated in the form of a Latin square, have been listed. The results for the dry matter and nitrogen have been summarized in Table 3.

The mean coefficients have been arranged both by periods and by animals with the respective ranges of variation and F values. Since there were two missing values the analysis of variance was made by first arranging

TABLE 3.—MEAN COEFFICIENTS OF DIGESTIBILITY OF DRY MATTER AND NITROGEN OF TOTAL RATIONS ARRANGED BY PERIODS AND BY ANIMALS. (MISSING VALUES INCLUDED IN MEANS, MEANS BASED ON SIX VALUES)

Coefficients of digestibility of dry matter arranged by periods and by animals				Coefficients of digestibility of nitrogen arranged by periods and by animals			
Periods		Animals		Periods		Animals	
Period No.	Coeff. %	Animal No.	Coeff. %	Period No.	Coeff. %	Animal No.	Coeff. %
1	65.2	11	65.5	1	75.8	11	75.8
2	65.0	12	65.4	2	77.0	12	76.2
3	65.0	13	63.7	3	76.0	13	75.6
4	64.6	14	65.4	4	75.4	14	76.8
5	64.7	15	64.5	5	75.3	15	74.2
6	65.2	16	65.5	6	76.3	16	77.4
Range	0.6	Range	1.8	Range	1.7	Range	3.2
F. values*	†	F. values*	5.24	F. value*	†	F. value*	1.69

* At P = 0.05, nec. F = 2.07.
† Variance for period less than error variance.

TABLE 4.—MEAN COEFFICIENTS OF DIGESTIBILITY OF OIL CAKE MEAL CALCULATED FROM MIXED RATIONS WITH HAY ARRANGED BY LEVELS OF OIL CAKE MEAL. (COEFFICIENTS IN PER CENT, MEANS OF SIX VALUES)

Level of oil cake Kg.	Coefficients of digestibility of different nutrients in per cent							T.D.N. in per cent of dry matter
	Dry matter	Organic matter	Nitrogen	Ether extract	Crude fibre	N-free extract	Total carbo-hydrates	
1	80.0	82.8	86.3	95.8	54.8	84.1	79.1	93.2
2	77.3	80.0	87.3	96.8	37.0	82.4	74.3	91.4
3	77.8	80.2	87.0	95.4	36.4	83.0	74.7	91.1
4	76.4	78.6	87.4	96.4	33.9	80.9	72.4	90.3
5*	76.0	78.3	87.2	96.0	25.4	81.5	71.3	90.4
Range	4.0	4.5	1.1	1.4	‡	3.2	7.8	2.9
F†	5.63	6.35	§	§	‡	§	5.48	§
Nec. diff.	2.0	2.1	§	§	‡	§	3.8	§

* Approx. 5 Kgs. according to capacity of animal.
† Nec. F at P of 0.05 = 2.87.
‡ Error too great for statistical analysis.
§ Differences between rations not statistically significant.

the data according to rations and periods and then by arranging them according to rations and animals. The missing plot technique of Yates was used (5).

It is evident that there were no significant differences in the coefficients of digestibility of dry matter and nitrogen between the six periods nor for the nitrogen between the six animals. In the case of the dry matter, the mean for animal 13 was slightly lower than the rest. There were no significant differences between the other five.

The coefficients of digestibility of linseed oil meal in the 5 mixed rations with hay were calculated by differences from the values of hay determined alone and the values of the total rations. These have been arranged by animals and levels of feeding in the Appendix, accompanied by an analysis of variance (Tables 12 and 13). The data are summarized in Table 4.

It will be observed that the digestibility of the nitrogen and ether extract remained constant throughout the entire range of feeding. The digestibility of the total carbohydrates showed a progressive decrease from the lowest to the highest level. This was statistically significant. The values at the lowest level were higher than the other four. The differences between these latter were not statistically significant, although there was a slight progressive decrease in digestibility with increasing levels. The results with the dry matter and organic matter were similar. While the digestibility of the nitrogen free extract and the total digestible nutrients also decreased as the level was increased the differences were not statistically significant. With the so-called crude fibre fraction the error was too large to justify a statistical analysis. It is of some significance, however, that the digestibility of this fraction was quite high at the lowest level, and showed the greatest decrease of all nutrients as the level of feeding reached the highest level.

In this experiment, therefore, it may be concluded that the level of feeding had no influence on the digestibility of the nitrogen nor on the ether extract. It did cause a moderate change in the digestibility of the carbohydrate fraction, particularly the crude fibre fraction. This change was inversely proportional to the level of feeding. It may be estimated that over the whole range there was a loss in total digestible nutrients of from 2 to 3 per cent. This finding confirms those of the previous publication (3).

TABLE 5.—PLANE OF NUTRITION OF RATIONS EXPRESSED IN TERMS OF MAINTENANCE ACCORDING TO BRODY'S STANDARDS (MEAN VALUES FOR EACH RATION BASED ON MEAN LIVE WEIGHTS OF ANIMALS FOR SIX PERIODS FOR EACH RATION)

Ration	No. of individual values	T.D.N., daily Kgs.			Dig. crude protein daily gms.*		
		Required	Consumed	Per cent of maintenance	Required	Consumed	Per cent of maintenance
Hay	4	3.05	3.17	106	316	301	97
Hay + linseed oil meal 3 : 1	6	2.97	2.28	76	308	468	150
Hay + linseed oil meal 3 : 2	6	2.96	3.11	104	307	812	261
Hay + linseed oil meal 3 : 3	6	3.00	3.95	132	311	1148	369
Hay + linseed oil meal 3 : 4	6	2.99	4.76	159	310	1494	480
Hay + linseed oil meal 3 : 5†	6	3.02	5.60	187	313	1864	599

* Dig. N × 6.25.
† Approximately 5 according to capacity of animals.

The levels of feeding have been translated into terms of maintenance requirements using Brody's tables (1) and expressed as planes of nutrition. In Table 5 are given the total digestible nutrients and the digestible crude protein consumed daily from the different rations compared with the maintenance requirements. In the case of the total digestible nutrients the plane of nutrition varied from 0.8 to 1.9 times maintenance and in the case of the digestible crude protein the plane varied from 1.5 to 6 times maintenance.

SUMMARY AND CONCLUSIONS

1. Using six grade Shorthorn steers, digestibility trials were carried out on six rations, one of hay, predominately timothy, and five of the same hay with increasing quantities of linseed oil meal.

2. The hay was fed at levels of 6.5 kilograms when given as the sole ration and 3 kilograms when given in the mixtures with the linseed oil meal. The latter varied from 1.0 to approximately 5.0 kilograms.

3. Coefficients of digestibility of the linseed oil meal were calculated from the five mixed rations.

4. As the level of feeding was increased, neither the protein nor the ether extract showed any significant change in digestibility while the carbohydrate fraction showed a progressive decrease.

5. This decrease was statistically significant in the case of the total carbohydrates, dry matter and organic matter.

6. The loss in total digestible nutrients over the entire range of feeding was between 2 and 3 per cent. This range in terms of plane of nutrition varied from 0.8 to 1.9 times TDN requirements for maintenance.

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APPENDIX

TABLE 6.—SCHEDULE OF EXPERIMENT

(Ration numbers shown by Roman numerals, animal numbers and period numbers by Arabic numerals)

Period No.	Commencing date	Rations arranged by following animal numbers					
		11	12	13	14	15	16
1	Nov. 9, 1946	VI	V	I	II	III	IV
2	Dec. 3, 1946	II	III	V	IV	I	VI
3	Jan. 4, 1947	III	VI	IV	I	V	II
4	Jan. 28, 1947	IV	I	II	V	VI	III
5	Mar. 1, 1947	V	IV	VI	III	II	I
6	Mar. 26, 1947	I	II	III	VI	IV	V

TABLE 7.—CONSTITUTION OF RATION

Ration No.	Weights, daily, kilograms		Ration No.	Weights, daily, kilograms	
	Hay	Oil cake		Hay	Oil cake
I	6.5 – 7.0	0.0	IV	3.0	3.0
II	3.0	1.0	V	3.0	4.0
III	3.0	2.0	VI	3.0	5.0*

* Approximately, varied slightly according to capacity of individual animal.

TABLE 8.—COEFFICIENTS OF DIGESTIBILITY OF HAY AND OF MIXED RATIONS OF HAY AND OIL CAKE MEAL (COEFFICIENTS IN PER CENT)

Ration	Period	Animal	Coefficients of digestibility						T.D.N. in per cent dry matter
			Dry matter	Organic matter	Nitrogen	Ether extract	Crude fibre	N.F.E.	
Hay 6.5	1	13	57.2	58.3	52.7	22.1	50.1	66.1	55.1
Kg. to 7.0 Kg.	2	15	56.8	57.6	56.1	42.6	53.7	61.1	54.8
	4	12	55.5	56.3	53.2	35.6	51.7	60.8	52.6
	5	16	57.4	58.8	56.4	43.3	57.0	60.4	55.1
Hay 3 Kg.	1	14	62.8	64.7	76.3	76.5	50.7	69.5	65.3
Oil cake 1 Kg.	2	11	64.2	65.8	76.7	80.4	57.0	67.3	66.4
	3	16	63.7	65.3	77.2	77.1	54.7	68.9	66.1
	4	13	61.3	62.9	73.5	79.4	49.2	67.6	63.0
	5	15	62.0	64.0	66.0	76.5	56.3	65.4	62.8
	6	12	62.9	63.5	74.6	77.3	52.1	67.1	63.7
Hay 3 Kg.	1	15	64.6	66.5	78.8	85.4	46.7	71.3	69.3
Oil cake 2 Kg.	2	12	66.7	68.0	80.5	89.4	54.3	69.5	71.0
	3	11	65.5	67.6	78.3	85.8	50.2	72.4	70.5
	4	16	65.6	67.7	80.5	86.8	54.9	69.0	70.8
	5	14	65.1	67.1	79.4	85.0	52.7	69.6	69.7
	6	13	63.9	65.5	49.5	83.8	46.6	69.8	68.0
Hay 3 Kg.	1	16	68.3	70.0	82.1	88.6	46.9	74.5	74.1
Oil cake 3 Kg.	2	14	67.8	69.8	81.8	87.5	52.5	72.3	74.0
	3	13	66.2	68.1	80.8	85.5	46.1	73.1	72.1
	4	11	67.8	69.6	79.7	89.1	50.9	72.2	73.1
	5	12	67.6	69.0	82.3	89.7	52.2	70.4	73.3
	6	15	67.6	69.5	81.5	87.1	50.7	72.9	73.4
Hay 3 Kg.	1	12	69.3	70.8	83.6	91.4	49.3	74.9	77.2
Oil cake 4 Kg.	2	13	66.0	67.8	82.2	90.5	44.5	69.6	73.1
	3	15	67.4	69.5	80.9	90.2	44.8	74.7	74.7
	4	14	68.8	70.6	84.6	91.0	50.2	72.6	76.4
	5	11	68.8	70.6	83.1	89.9	49.9	73.2	75.8
	6	16	69.2	70.9	83.5	90.3	50.6	72.4	75.8
Hay 3 Kg	1	11	69.1	71.0	81.6	92.0	39.7	75.3	77.0
Oil cake 5 Kg.*	2	16	68.6	70.4	84.9	92.5	44.9	73.9	76.6
	3	12	70.2	71.8	84.2	92.2	42.1	76.6	77.7
	4	15	68.4	70.6	82.2	90.3	48.0	73.0	76.3
	5	13	67.5	69.4	84.6	88.9	46.9	70.9	78.8
	6	14	70.5	72.2	84.3	91.3	47.8	75.4	77.8

* Approximately, according to capacity of animal.

TABLE 9.—COEFFICIENTS OF DIGESTIBILITY OF DRY MATTER AND NITROGEN OF TOTAL RATIONS ARRANGED BY RATIONS, PERIODS AND ANIMALS. (COEFFICIENTS IN PER CENT, ANIMAL NUMBERS IN BRACKETS)

Nutrient	Period No.	Coefficients of digestibility of rations						Means
		Hay	Hay 3 LOM 1	Hay 3 LOM 2	Hay 3 LOM 3	Hay 3 LOM 4	Hay 3 LOM 5*	
Dry matter	1	57.2 (13)	62.8 (14)	64.6 (15)	68.3 (16)	69.3 (12)	69.1 (11)	65.2
	2	56.8 (15)	64.2 (11)	66.7 (12)	67.8 (14)	66.0 (13)	68.6 (16)	65.0
	3	— (14)	63.7 (16)	65.5 (11)	66.2 (13)	67.4 (15)	70.2 (12)	66.6†
	4	55.5 (12)	61.3 (13)	65.6 (16)	67.8 (11)	68.8 (14)	68.4 (15)	64.6
	5	57.4 (16)	62.0 (15)	65.1 (14)	67.6 (12)	68.8 (11)	67.5 (13)	64.7
	6	— (11)	62.9 (12)	63.9 (13)	67.6 (15)	69.2 (16)	70.5 (14)	66.8†
	Means	56.7†	62.8	65.2	67.6	68.2	69.0	
Nitrogen	1	52.7	76.3	78.8	82.1	83.6	81.6	75.8
	2	56.1	76.7	80.5	81.8	82.2	84.9	77.0
	3	—	77.2	78.3	80.8	80.9	84.2	80.3†
	4	52.2	73.5	80.5	79.7	84.6	82.2	75.4
	5	56.4	66.0	79.4	82.3	83.1	84.6	75.3
	6	—	74.6	79.5	81.5	83.5	84.3	80.7†
	Means	54.4†	74.0	79.5	81.4	83.0	83.6	

Means for animals

	An. 11	An. 12	An. 13	An. 14	An. 15	An. 16
Dry matter	67.1†	65.4	63.7	67.0†	64.5	65.5
Nitrogen	79.9†	76.2	75.6	81.3†	74.2	77.4

* Approximately 5 Kgs. according to capacity of animal.
† Not including estimates of missing values.

TABLE 10.—ANALYSIS OF VARIANCE OF PERIODS IN TABLE 9*

Nutrient	Variance due to	D/F	Sums of squares†	Variance†	F
Dry matter	Ration + period	10	499.51		
	Period	5	1.88	0.38	‡
	Error	23	27.89	1.21	
Nitrogen	Ration + period	10	2744.53		
	Period	5	11.68	2.34	‡
	Error	23	116.72	5.07	

* Using method of Yates (5) for missing values.
† Calculated to four decimal places, reported in table to two places.
‡ Variance less than error variance.

TABLE 11.—ANALYSIS OF VARIANCE OF ANIMALS IN TABLE 9*

Nutrient	Variance due to	D/F	Sums of squares†	Variance†	F	Nec. F. at P = 0.05
Dry matter	Ration + animal	10	513.48			2.64
	Animal	5	15.86	3.17	5.24	
	Error	23	13.91	0.61		
Nitrogen	Ration + animal	10	2767.42			2.64
	Animal	5	34.57	6.91	1.69	
	Error	23	93.83	4.08		

* Using method of Yates (5) for missing values.
† Calculated to four decimal places, reported in table to two places.

TABLE 12.—COEFFICIENTS OF DIGESTIBILITY OF LINSEED OIL MEAL CALCULATED FROM MIXED RATIONS WITH HAY

Ration (Kg. oil meal)	Animal No.	Coefficients of digestibility of linseed oil meal in per cent							T.D.N. in per cent of dry matter
		Dry matter	Organic matter	Nitrogen	Ether extract	Crude fibre	N-free extract	Total carbo-hydrates	
1	11	85.1	88.1	90.6	101.3	98.0	83.5	86.5	99.5
	12	80.2	79.6	86.3	91.3	40.9	82.5	74.5	90.4
	13	74.4	77.3	85.1	99.8	3.9	83.9	68.8	88.7
	14	80.0	83.9	91.0	91.3	19.9	91.1	79.9	94.5
	15	76.9	81.2	73.5	97.0	89.7	75.1	78.2	87.9
	16	83.5	86.7	91.0	94.3	76.4	88.7	86.8	98.3
2	11	78.1	81.6	85.5	96.2	30.5	87.2	78.2	91.9
	12	80.9	82.2	88.7	102.0	60.4	81.1	76.9	94.0
	13	74.0	76.2	86.8	91.9	9.1	81.8	67.8	87.3
	14	76.8	79.9	87.4	97.4	50.4	80.5	74.2	91.8
	15	75.7	78.6	86.9	94.5	6.5	84.6	72.5	89.4
	16	78.1	81.6	88.5	98.8	65.0	79.2	76.5	93.8
3	11	78.3	80.7	85.0	97.4	42.6	82.2	74.7	91.1
	12	77.8	79.3	88.2	98.8	48.9	78.5	72.3	91.4
	13	75.2	77.9	86.1	92.4	14.4	83.6	72.7	88.6
	14	78.3	81.0	87.6	95.6	50.5	82.9	76.3	92.1
	15	77.8	80.5	86.7	92.9	41.3	84.1	75.8	91.4
	16	79.1	81.4	88.2	95.0	20.6	86.4	76.1	92.0
4	11	77.2	79.5	87.7	96.8	41.5	81.2	72.9	91.2
	12	78.1	79.9	88.4	96.5	37.4	84.2	76.9	92.7
	13	72.5	74.7	86.6	96.8	22.1	75.6	64.7	86.0
	14	77.3	79.5	89.2	97.4	42.0	80.5	73.2	92.2
	15	75.1	77.8	85.0	95.9	16.9	83.8	73.2	88.9
	16	78.0	80.0	87.7	94.9	43.5	80.3	73.2	90.9
5*	11	75.1	77.4	84.7	95.6	9.8	82.1	70.8	87.9
	12	77.6	79.4	87.7	96.8	13.6	84.6	73.5	90.3
	13	73.5	75.9	88.0	94.3	33.8	76.1	67.2	92.7
	14	78.6	80.6	87.9	95.2	34.9	83.9	74.5	91.7
	15	75.3	78.1	85.8	95.6	35.9	79.8	71.5	89.5
	16	76.0	78.3	89.1	98.4	24.6	82.2	70.4	90.3

* Approximately 5 Kgs. according to capacity of animal.

TABLE 13.—ANALYSIS OF VARIANCE OF DATA IN TABLE 12

Nutrient	Variance due to	D/F	Sums of* squares	Variance*	F	Nec. F. at P = 0.05
Dry matter	Ration	4	59.60	14.90	5.63	2.87
	Animal	5	103.89	20.78	7.85	2.71
	Error	20	52.92	2.64		
Organic matter	Ration	4	77.11	19.28	6.35	2.87
	Animal	5	95.93	19.19	6.32	2.71
	Error	20	60.71	3.04		
Nitrogen	Ration	4	5.26	1.32	†	
	Animal	5	94.93	18.99	2.20	2.71
	Error	20	172.21	8.61		
Ether extract	Ration	4	7.28	1.82	†	
	Animal	5	26.63	5.33	†	
	Error	20	169.94	8.50		
Crude fibre	Ration	4	2756.21	**		
	Animal	5	2838.00	**		
	Error	20	10438.34	**		
N-free extract	Ration	4	38.14	9.54	†	
	Animal	5	46.31	9.26	†	
	Error	20	281.85	14.09		
Total carbohydrates	Ration	4	217.30	54.32	5.48	2.87
	Animal	5	246.84	49.37	5.98	2.71
	Error	20	198.30	9.91		
T.D.N. in dry matter	Ration	4	32.96	8.24	1.27	2.87
	Animal	5	80.98	16.20	2.50	2.71
	Error	20	129.61	6.48		

* Calculated to four decimal places, reported in table to two places.
† Variance less than error variance.
** Variance too large.

THE PHYSIOGRAPHY OF THE AGRICULTURAL AREAS OF BRITISH COLUMBIA

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Keen interest has been shown recently in the extent of the agricultural lands in British Columbia. Comprehensive appraisals of the nature and extent of these lands have not been attempted for some time. Perhaps the diversity prevailing in the surface features of the province, over even short geographical distances, has discouraged attempts at description. However, a broad physiographic picture appears to offer a logical background upon which a sound appraisal of agricultural lands in British Columbia may be based. While it may not yield such pertinent information as acreage and soil type, it will indicate the location of important areas and their probable size.

THE REGIONAL PHYSIOGRAPHY AND ITS DIVISIONS

The political province of British Columbia falls almost entirely within the North American Cordillera. Only north-eastern British Columbia falls within the Great Plains or the Tramontane region. In British Columbia, as indeed over most of its length, the Cordillera may be divided into three longitudinal belts, western and eastern, both with a highly uneven topography with high summits and deep valleys, and a central belt with lower summit elevations and a semi-plateau topography. The transitions between the belts are broad and definite boundaries are often hard to discern.

Within the three belts the physiographic provinces are often quite well defined by reason of deep rather continuous structural valleys which parallel the belts or cut across them at usually acute angles. These provinces are well designated by Kerr (39) and Schofield (61) and others (19) and are portrayed in Figure 1. In our modification the trenches are given the same status as the mountain ranges.

The Western (or Pacific) Belt is partitioned by a major downfold, the Coastal Trench, which extends clearly defined from southern Washington into the Alaskan Panhandle. The trench is probably structural in origin (46), rather than erosional (50), and structural relationships with the Willamette Valley of Oregon and the San Joaquin and Sacramento Valleys of California might be claimed. West of the trench in British Columbia lie the Insular mountains, that is, the mountains of Queen Charlotte and Vancouver Islands. East of the trench lies the Coast Range which, for all practical considerations, extends from the southern to the northern boundaries of the province. A few (61) recognize the Cascade Range, which lies south of the canyon and delta of the Fraser River and extends far southward into the Pacific Coast States, as being separate.

The Central Belt, often referred to as the Interior Belt of Plateaux, in following the general N.W.-S.E. trend of the Cordillera, is limited in extent along the southern border of the province but occupies a great area in the

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FIGURE 1. Physiographic Divisions of British Columbia.

central portion and appears to be maintained fairly definitely to the northern border. The physiographic provinces within this belt are not easily defined although a definite basis for division may exist (46) for the southern part. The Fraser Plateaux (southern section) and the Nechako Plateaux (central) are divisions currently recognized.

The Rocky Mountain Trench, a principal structural valley which follows the general longitudinal trend of the mountain chains, separates the two principal mountain masses in the eastern belt. The trench, one of the major physiographic features of the continent, has great length; it is detectable as far south as Flathead Lake in Montana, extends northwestward through British Columbia, and fades out in the Yukon territory near the Arctic Circle. The Columbian Mountains to the west of the trench consist of several parallel ranges and trenches and extend from Idaho and Montana to Central British Columbia to a point where the Rocky Mountain trench and Interior Plateaux seem to connect. However, northward the counterpart of these mountains is again in evidence in a system tentatively designated as the Omineca Mountains. The Rocky Mountains to the east of the trench are a long, uniform mountain chain and include a few structural valleys. No subdivisions of importance are recognized within these mountains from the 49th parallel to the Liard River near the northern border of the province. Only once, in the vicinity of Peace River Pass, is the series of high mountain summits broken appreciably.

The Tramontane area of north-eastern British Columbia is essentially part of the Great Plains physiographic province (1). In conforming with the underlying rocks, the surface is essentially one of low relief. Some highland plateaux, possibly northern counterparts of the Cypress and Sand Hills of Alberta are seen above the general plains surface in the far northeast.

For the purpose of giving a simplified picture the following few physiographic divisions have been recognized. The Belts and their divisions deserve the status, respectively, of physiographic regions and provinces.

The Western Mountainous Belt
- *(a)* The Insular Mountains.
- *(b)* The Coastal Trench.
- *(c)* The Coastal Mountains.

The Central Belt of Interior Plateaux
- *(a)* The Fraser Plateaux.
- *(b)* The Nechako Plateaux.

The Eastern Mountainous Belt
- *(a)* The Columbian (and Ominecan) Mountains.
- *(b)* The Rocky Mountain Trench.
- *(c)* The Rocky Mountains.

The Tramontane Plains

THE INSULAR MOUNTAINS

Bordered by the Pacific Ocean the westernmost physiographic division of the province is constituted in the mountains of Queen Charlotte and Vancouver Islands. The chain of mountains is not uniformly developed. To the south the mountains of Vancouver Island are separated from the Olympic Mountains of Washington State (to which they bear relationship) by the deep ocean-filled channel, Juan de Fuca Strait. The summit elevations of Vancouver Island seldom exceed 3000 ft. but in the north a few exceed 7000 ft. The chain is broken again by the salt water filled trough, in part known as Queen Charlotte Sound, between Vancouver Island and the Queen Charlottes. Three summits in the latter group just exceed 3000 ft.

The rocks forming the core of the Insular mountains are altered sedimentaries and volcanics largely of Carboniferous and Jurassic ages and, if contrast is made with the Coast Range to the east, have conferred upon the Insular mountains a relatively subdued form. The Insular range, however, has many erosional features in common with the Coast Range and Interior Plateaux. By late Tertiary times, over the southern and central parts of the province, erosion had reduced the land surface to a fairly high degree of uniformity especially in the southern part. The old upland surface is now represented in a striking concordance of summit and ridge elevations. The present "upland surface" in the south is about 1200 ft., in the north 3500 ft. Uplift and erosion occurred at the close of the Tertiary and prior to the Pleistocene a new coastal plain had developed on the flanks of the Insular mountains (13, 14, 15, 16).

During the Pleistocene period the Insular province was covered, except for a few high summits, at least twice, by ice (13, 25). Tertiary valleys, both subsequent and transverse, were severely modified by ice action. Fiord development is marked on the western slopes and less marked on the eastern slopes. Post glacial influences in the mountains are not striking; a recent uplift of some 150 ft. – 500 ft. is evident in the stream gradients (64). Drainage, not simple, is principally to the east and west from the Range axis.

Insular Mountain Soils

(a) The Alberni Basin

One intermountain basin of some 100 sq. miles area possesses a topography suitable for agriculture. The basin (Figure 2) in which the city of Alberni is located appears to be an old subsequent valley of obscure origins carved out of "soft" Cretaceous and Tertiary sediments. It is connected with the long Alberni fiord on the west, on the east by a low pass to the coastal plain of eastern Vancouver Island and on the north and south with several fiord-like lake filled valleys. At its widest the basin is 15 miles, was probably well defined in Tertiary times, and has been filled with glacial and post glacial deposits. Marine, lacustrine and stream action have resorted the glacial debris and some recent allluvium has been deposited. There is in all some 45,000 acres of land with a topography suitable for arable agriculture, 30,000 acres of which is stony and coarse. About 4000 acres are now cultivated (64, 65). The basin contains some of the finest forest soil in British Columbia.

On southern Vancouver Island some flat swamp covered areas on the old land surface have a limited agricultural value.

(b) The Tofino-Long Beach Platforms

Conveniently considered with the Insular mountain province are the narrow strips of lowland which occur at intervals along the west coast of Vancouver Island. These are remnants of a coastal plain built up against submerged mountain slopes as small embayments in Tertiary times (16). The lowland strips are seldom more than 1 or 2 miles wide and are mainly underlain by soft sedimentary rocks; a few planed granites and crystalline rocks also underlie some sections. The areas were spared intense glacial action. They appear to represent marine platforms submerged in the Pleistocene and recently elevated from the sea in a post glacial uplift of 300 ft. The acreage of arable land is probably small but at present supports a few farms and airfields.

No other areas of agricultural value have been recognized in the mountain belt of Vancouver Island.

The arable lands in the insular province are well leached podsols; the climax vegetation is principally heavy coniferous forest.

THE COASTAL TRENCH

The belt or trench of depressed land separating the two more or less parallel members of the Pacific mountain belt, and extending with a few interruptions from the Gulf of California to Cook Inlet, Alaska, in British Columbia takes the form of a series of submerged longitudinal basins.

FIGURE 2. Alberni Basin on Vancouver Island. The macrotopography is uniform, the microtopography, rough. Excellent forest soils; some arable resorted till and alluvium.

R.C.A.F. Photo

FIGURE 3. Lower Fraser Valley (Chilliwack District) showing alluvial delta with the Hope Mountains rising sharply in the background.

—Artray Photo

FIGURE 4. Bella Coola Valley in the Coastal Mountains. A typical U-shaped valley, silt filled, at the head of a major fiord.

—R.C.A.F. Photo

FIGURE 5. "White Silts" at Summerland in the Okanagan Trench. They present a bold cliff-like appearance near the lakeshore but dip gently above. Orchard development here is almost confined to the "White Silts".

—R.C.A.F. Photo

Peacock (50) has subdivided this physiographic division in British Columbia into two sections, the Hecate Basin comprising part of Graham Island, Queen Charlotte and Millbank Sounds and the Gulf of Georgia Basin comprising Puget Sound, the Lower Fraser Valley, the coastal plain along the eastern shore of Vancouver Island, and the Gulf of Georgia. The two basins are connected by the relatively narrow passage of Johnstone Strait. In the latitudes of British Columbia much of this division is ocean filled. An emergence of only 600 ft., however, would create two great valleys occupied by a few lakes and almost completely surrounded by mountains.

The origin of the Coastal Trench is a matter of some dispute. It is variously described as a "downfold," a "trench" and an "intermont valley belt." In Cretaceous times sediments of considerable thickness, limestones and shales, were laid down in the basins. To-day these are exposed along the above water fringes of the trench and are often associated with the topographically uniform areas of agricultural importance. Sedimentation again occurred in Tertiary times and, again around the basin margins, Tertiary sedimentaries are associated with lands topographically suitable for agriculture.

During the Pleistocene, certainly once and probably twice, the Georgia basin was filled with southward moving ice. At the ice front, south of Tacoma in Washington State, a thickness of 1500 ft. was probably attained; farther north the ice was at least 6000 ft. thick. Little is known of the influence of ice in Hecate Basin. Local glaciation may have lightly eroded the lowland on Graham Island in the Queen Charlottes (44).

The southward movement of the Gulf of Georgia glacier unmistakably modified the surface features along the now exposed basin margins. High wave cut cliffs conspicuously mark outwash deposits around Puget Sound and the Gulf. Glaciers too from the fiord land to the east deposited great quantities of debris. Two till sheets, both of Wisconsin time and one interglacial deposition are recognized (9, 25, 33).

A post glacial uplift of several hundred feet is deduced from the presence of raised beaches, wave cut terraces and cliffs along the margins of the basins. In the lower Fraser Valley the uplift has exceeded 600 ft. (31); on eastern Vancouver Island and the Queen Charlottes it was much less.

The Arable Areas of the Coastal Trench

While much of the coastal trench in British Columbia is submerged the non-submerged areas comprise one of the largest agricultural parts of the political province.

(a) The East Coast Plain of Vancouver Island

Associated with the Gulf of Georgia Basin are the principal agricultural soils of Vancouver Island (Figure 10). The coastal plain, on eastern and southern Vancouver Island, underlain by "soft" basin rocks or planed crystalline rocks has provided a suitable surface for accumulation and deposition of a soil mantle. The plain varies in width from 1 to 15 miles and breaks sharply with the insular mountains. Its elevation ranges from

100 ft. to 500 ft. While there are several valleys paralleling the plain and while the Gulf Islands and their troughs are predominantly north to south in trend, all of the many streams from the Insular mountains and coastal swamps flow eastward across the plain sometimes dissecting it quite deeply. Weak marine terraces and beaches are found across the plain up to the 350 ft. contour. Wave cut cliffs characterize much of the present coast. Deltas both raised and recent are found at the mouths of most of the streams. In the Victoria area a number of small basins, filled with marine tills, silts and sands, have risen from the Pleistocene Sea to provide some of the best farmland on the Island. While the macrotopography of the Coastal Plain appears favourable for the development of large areas of arable land the microtopography belies the impression. The microsurface of the coastal plain of Vancouver Island is, except for the scattered recent deltas and lacustrine deposits, rough. Excessively drained terraces, knolls and moraines, and poorly drained flats make for a heterogeneous soil pattern over all sections. Of 625,000 acres of coastal plain surveyed, Spilsbury (65) found only 200,000 arable with 90,000 already occupied. Perhaps an additional 200,000 acres of basin lands remain to be soil surveyed in the Gulf Islands and Northeastern coast of Vancouver Island; most of this, however, is poorly drained or has a thin soil mantle. Some of the superior forest soils of the continent are on the Island plain.

(b) The East Coast Plain of Graham Island

Graham Island the largest of the Queen Charlotte group is the only island having some surface suitable for arable agriculture. Abutting the Insular mountains on the northeastern corner of the island is one of the largest smooth land surfaces in British Columbia (1, 44). It occupies about one-third of the island, some 1800 sq. mi. The area is underlain by partially or wholly unconsolidated sediments of Tertiary age with some areas of younger Tertiary volcanics. The surface is low and undulating with few points over 200 ft. elevation. Shallow lakes occur frequently and streams crossing the plain meander conspicuously. Much of the Graham Island plain may have been submerged in recent times; evidence for this lies chiefly in the wave cut cliffs of the eastern shore. Glacial action appears to have been limited to the Insular mountains and even here it was probably slight.

While much of the soil of the lowland area is fine and has a satisfactory topography it is seldom classed with the agricultural resources because of the cover of muskeg and dense forest.

(c) The Lower Fraser Valley

Another agricultural area properly associated with the Coastal Trench is a transverse valley or embayment on the eastern side of the Gulf of Georgia, the Lower Fraser Valley (Figure 11). It enjoys a continuous connection with the Puget Sound plain in Washington State to the south and a broken relationship with limited areas of Cretaceous and Tertiary basin rocks to the north. The fan-shaped lowland is about 80 miles from the Gulf waters to the Valley head and about 40 miles across the front. The lowland floor breaks sharply with Coast Range Mountains of 4000—8000 ft. in elevation to the north and high Cascade Mountains to the

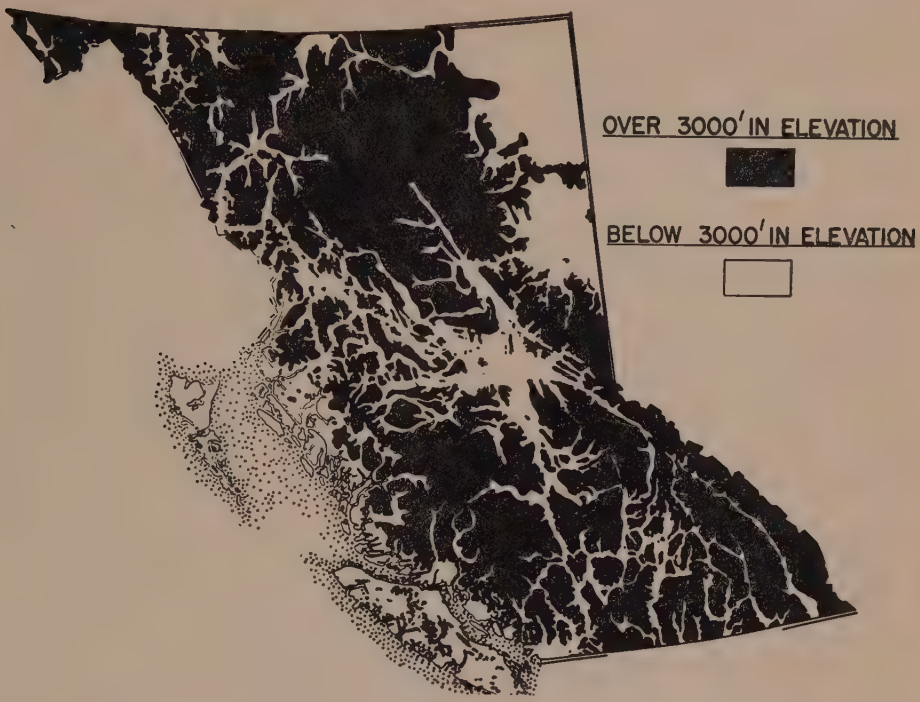

FIGURE 6. General agriculture, apart from range livestock production, cannot be successfully carried on at elevations of over 3000 feet in most of British Columbia. Less than 25 per cent of the total area of the province lies below the 3000 feet contour.

south. Altered Cretaceous sediments and consolidated Tertiary sandstones, shales and conglomerates outcrop occasionally sometimes up to the 800 ft. contour along the mountains. Downwarping and erosion of these basin rocks has occurred but glacial detritus and recent alluvium have filled in to give the whole a fairly uniform surface. At the eastern end of the lowland the fill has built up around steep-sided "nunataks" such as Vedder and Sumas mountains.

During the Pleistocene the lowland was covered with ice to a probable depth of 5000 ft. Ice, from the Gulf of Georgia glacier, from the great fiords to the north, such as the Pitt and Harrison valleys now lake-filled, and from the Hope Mountains (Cascades) must all have contributed to the Pleistocene history of the Lower Fraser Valley. Some interglacial deposits and two till sheets are recognized in the area (38). Retreat of the ice and the accompanying post glacial uplift of 600 or 700 ft. is evidenced over the lowland surface in old marine beaches and weak terraces, in abandoned channels of post glacial streams, in kettles and moraines (48).

Across the lowland area (Figure 3) flows the silt laden Fraser river. Below Yale, where the river emerges from its Coast Range Canyon, the stream takes a direct course to the sea. Ten miles from its debouchement at the Gulf its water splits into several channels. Over much of its length across the lowland the river is tidal. At Yale, Hope and possibly at Chilliwack the river is cutting into its raised deltas. Across a wide front and over a large area in the Gulf of Georgia the river is depositing. The

delta front appears to be advancing 12 ft. a year (30, 32). The filling of the lowland with till and alluvium has "dammed" the fiord valleys of several large streams flowing from the Coast Mountains on the north. As a consequence a number of these valleys are now, or were recently, lake-filled. Some of the lakes such as Pitt Lake and Harrison Lake are 35 miles in length.

Some 500,000 acres of land in the Lower Fraser Valley is topographically suitable for agriculture and by virtue of its proximity to large centres of population almost all must be classed as agricultural. Recent "delta" or lowland soils principally clays, loams and peats, obtain over 45 per cent of the area; upland soils, mainly glacial till, moraine and loess, varying in texture from loam to sand, comprise another 25 per cent of the arable land; about 30 per cent of the area is in upland soil with adverse topography or excessive subdrainage (35). Most of the lowland has been dyked and ploughed. Considerable areas of upland remain in second growth forest.

The upland soils of the coastal trench are podsolic and except on southern Vancouver Island show incipient lateritic development. The colors in the surface horizons of the zonal soils range from reddish to yellowish brown. Much of the most productive farmland is associated with recent alluvium; here profile development is weak. Ortstein, Glei and bog soils are commonly found over the lowlands of the Coastal Trench.

THE COASTAL MOUNTAINS

From the Lower Fraser Valley northwestward into Alaska the great physiographic element, the Coastal Mountains extends in an almost unbroken chain. The range is built of great masses of plutonic rock, mainly grano-diorite, which "invaded" a heavy cover of sedimentary and volcanic rocks in Jurassic and Cretaceous times. Cover or roof rocks now exist only in isolated patches, mainly on the north-eastern side of the range. From sea level the range appears rugged but as in the insular mountains the peaks and close set ridges show a striking concordance in elevation. The range thus appears as a vast dissected plateau 100 miles wide and 1000 miles long with a vague gently arched longitudinal axis of 9000 ft. in south, rising to 11,000 ft. at latitude 52°. Farther north the axis drops, again to rise before the range is "lost" in Alaska. Peaks rise above the general axis level by as much as 3000 ft. The highest peak in the range, wholly in British Columbia, Mount Waddington, rises to 13,260 ft.

The principal drainages of this physiographic province are transverse to the trend. The largest rivers flow from the Interior Plateau through the range by way of deep valleys forming veritable corridors or gaps. Most of these streams such as the Fraser, the Homathko, the Kleena Kleene, the Dean, the Skeena, the Nass, the Stikine and the Taku are actually deepening their courses. The seaward margin of the range is riven by a maze of steep-sided tidewater inlets leading far into the range, a typical fiord land. Most of these have high steep parallel walls, are narrow and straight or cranked by abrupt deflections at high angles. A dominant structural pattern of valley elements arranged longitudinally and trans-

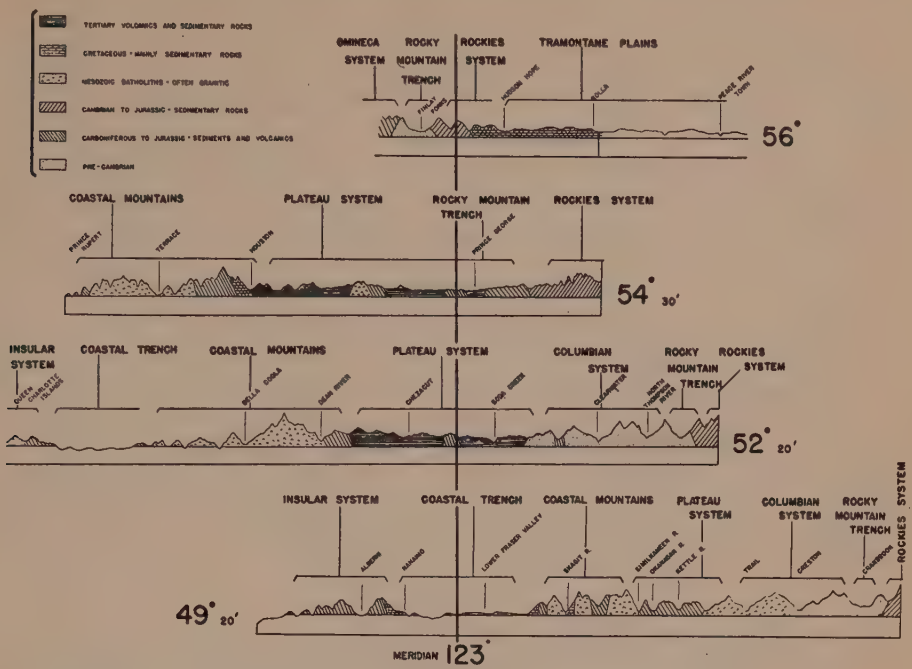

FIGURE 7. Cross sections of British Columbia at four latitudes showing approximate topography and nature of the country rock.

versely to the trend of the range can be distinguished accounting for much of the cranked nature of the fiords and interconnecting through valleys (50).

During the Pleistocene, ice moved southwestwardly from the Central Belt across the Coast Mountains chiefly by way of through valleys. While the higher peaks were not overridden, most of the range was severely modified by the ice and massive sheets of drift mantle the lower slopes of the ranges and margins of the coastal trench. In post glacial and glacial times sporadic volcanism has occurred.

Agricultural Lands Within the Coast Range

(a) The Mainland Fiord Heads

Only a few small areas, having agricultural value, exist in this physiographic province. Many streams, often glacier fed, eroding through bedrock and till have built up and are building up rapidly high grade deltas at the heads of the fiords. Only two deltas have seen any noteworthy agricultural development, the Squamish Valley at the head of Howe Sound and the Bella Coola valley (Figure 4) at the head of North Bentinck Arm. These areas embrace only a few thousand arable acres and support a small agricultural population. Much of the better land, the raised deltas and resorted drift, is subject to flooding by swift flowing streams.

(b) The Terrace Valleys

Two intermountain valley areas, Pemberton Meadows and the Terrace Valley are noteworthy. The Terrace area (40, 41, 42), close to sea level, on the Skeena River, enjoying a coastal climate, is located at the junction

of several drift filled valleys. It has close connections with salt water by way of the Skeena River and Kitimat Arm fiord. Much of the valley deposit is coarse drift; some is terraced semi-lacustrine and flood plain gravel, sand and loam. Much of the finer deposit undoubtedly originates in the recent unconsolidated volcanics of the area and in powder from glacier fed streams. The total acreage of topographically uniform land at Terrace is 66,000 acres and possibly 50 per cent is fine textured enough to be arable. These coarse valley soils, however, support an excellent forest growth.

(c) The Pemberton Valley

The Pemberton Meadows area consists of recent alluvium and raised delta deposited, at the head of Lillooet Lake, by glacier fed streams. The valley is long, steep sided and U-shaped on cross-section and at one point is over 7 miles wide. The elevation is comparatively low (1000 ft.). Unconsolidated quaternary volcanics and glacial flour have contributed heavily to the local stream loads. Stream control is important in the use of the arable lands, some 20,000 acres of reclaimable azonal soil.

The Interior Plateaux

The boundaries of the physiographic province in the central belt, usually known as the Interior Plateau, are difficult to place. The area is about 500 miles long, 100 to 300 miles wide and trends northwest from the 49th parallel. The eastern boundary, or contact with the Columbia Mountain System, may be roughly limited by the valleys of the Kettle, Adams, Clearwater and Willow Rivers. A branch of the Cascade range, known locally as the Okanagan range, bounds the plateau on the south. To the southwest from Lillooet to the 49th parallel the boundary area is broad and presents characters of both Interior Plateau and Coast Ranges. In the northwest central area, from Lillooet to Hazelton, the boundary is definite with foothills and mountain ranges breaking quite sharply with the plateau surface. The northern boundaries are, for want of information, difficult to define; the plateau surface, however, is probably recognizable in the far northern parts of the province (34).

The Okanagan and Similkameen valleys on the south drain to the Columbia River. By far the greatest river system draining the Plateau is that of the Fraser and its tributaries, the Thompson, the Chilcotin, and the Nechako Rivers.

The plateau province consists essentially of large areas of rolling upland separated from each other by deep valley trenches. In the south the plateau surface lies from 4000 to 6000 feet above sea level (Figure 7); its elevation gradually decreases towards the north where it may reach a minimum elevation of 2200 feet around Prince George. Since the main routes of travel are along main valleys with steep-sided eroded shoulders, the casual observer gains the impression, not of plateau but of mountainous upland. Actually streams crossing the upland generally have low gradients and are frequently dammed by small Pleistocene moraines to form extensive swamps and lakes. The upland surface, while not flat, is not mountainous. The areal ratio of upland to valley in the south is about 3 to 1; in the north, valley often merges imperceptibly with upland.

FIGURE 8. Areas in British Columbia within which agricultural soils may be found are in black. The map, adapted in large part from that of Whitford and Craig, shows the general distribution of agricultural lands in the province.

The present upland surface conforms only partially with the underlying rocks. In the strictest sense the term plateau is then not correct. Submergence in Carboniferous times is indicated in a wide distribution of limestones, quartzites and submarine flow rocks over the area. Granitic rocks, frequently occupying large areas in the south, witness the great plutonic intrusion which commenced in Jurassic times and which resulted in the first great elevation of the Coast Range and Columbian systems to the west and east. Cretaceous rocks occur along the western fringes of the plateau and point to a period of unroofing of the Coast Range batholith (27, 58).

During the early Tertiary, in the south at least, the area was probably rough. A number of isolated basins developed in which lacustrine sediments were deposited. A great resurgence of volcanism occurred later in the Tertiary, accompanied by the accumulation of great depths of lava; these depositions, lacustrine and volcanic, relatively undisturbed to-day, account for much of the level topography of the plateau surface. Still later in the Tertiary the plateau area was uplifted and many of the principal valleys were dissected. No part of the plateau remained free of ice during the Pleistocene. Glacial erosion, while not extreme in some places, was extensive in others. Fresh bedrock was exposed and much loose mantle swept into valleys. Ice and water scoured and remoulded many of the main valleys and disorganized existing drainage. As the ice retreated, lacustrine, flood plain and terrace series were laid down over widely scattered

areas and at nearly all elevations (47, 52, 38). Numerous lakes and relict streams which owe their existence to disorganized drainage are still extant. Adjustments, at least partly isostatic, are still taking place.

A number of physiographic subdivisions may be recognized in the Interior Plateau. In the south, Matthews (46) recognized three general N.W.-S.E. axes of elevation alternating with three axes of lesser uplift. In order from east to west the axes correspond to the Kettle Depression, the East Okanagan Highland, the Okanagan Depression, the West Okanagan Highland, the Princeton-Kamloops Depression and the Western Highlands. Only the lowlands have much agricultural interest.

(a) The Kettle Depression

The Kettle Depression is a rather small intermontane trough drained by the Kettle Rivers which flow south. The narrow trough is about 45 miles long. The plateau surface adjacent to the depression is fairly well preserved and arable lands are found upon it, viz., several thousand acres of dry farm land around Bridesville. Scattered post-glacial terraces and recent allluvium along the valley bottom, never more than 5 miles wide, support a limited agriculture. The agricultural area is nowhere more than three miles wide (Midway and Rock Creek) and is usually narrower. Some of the scattered arable land is irrigated and used for hay production, hay being a limiting factor in the use of adjacent range on valley side, upland and alpine surfaces.

(b) The East Okanagan Highland

The East Okanagan Highland, with a maximum summit elevation of 7000 feet, supports a small range sheep and cattle population. Soils are shallow at best and support a poor forest. Swamps and lakes in the area serve as reservoirs of irrigation water for adjacent lowland.

(c) The Okanagan Depression

The Okanagan Depression extends for at least 150 miles from the 49th parallel at Osoyoos to Shuswap Lake and constitutes the largest intermontane trough. The valley bottom in the south is 3 to 6 miles and in the north 12 to 15 miles wide (62). Armstrong, in the north, has an elevation of 1200 feet and Osoyoos, in the south, 800 feet. The valley floor surface shows some local relief, rarely exceeding 800 feet. Characteristically, the valley shoulders rise abruptly to the upland surface at 4000 to 6000 feet elevation and are often sharply dissected by youthful canyons made by subsequent streams flowing almost directly down from the tilted plateau surface. Drainage of the Okanagan Depression is effected by two major longitudinal streams—the Okanagan River (and Lake) flowing southward to the Columbia River and the Shuswap River (and Lake) flowing northward and westward to the Fraser River. An outstanding feature of the depression is the gradient produced by overdeepening through glaciation and some quaternary sedimentation. It is said that two dams, each less than 150 feet high, one at Okanagan Falls in the South Okanagan and one at Wallachin on the Thompson River, would produce a single waterway 275 miles long. Almost 60 per cent of the trough is now occupied by lakes, the direct or indirect results of glacial overdeepening, or damming

by alluvial fans and moraines. Important "East-West" valleys run into the trough in the north which in turn connects several broad valleys running parallel to it. A complex rectangular pattern of valleys thus formed involves several drainages separated by low passes. As bottoms and drainage channels of post-glacial lakes formed as the last Pleistocene ice sheet retreated, these valleys share a common but complex history.

The major agricultural soils of the Okanagan Valley are associated with striking terraces of laminated silt which flank the valley sides and fill its bottom (Figure 12). The terraces (Figure 5) are sharply cliffed at lake-shore but above are separated by moderate slopes. Their thickness varies but is commonly several hundreds of feet. Uppermost prominent terrace above Okanagan Lake is at the 1800 feet elevation which coincides well with the elevation of the outlet channel or spillway for the late Pleistocene Okanagan Lake placed by Flint (24) near Vasseaux Lake. The lacustrine or semi-lacustrine origin of the silts is established beyond doubt. It would seem that residual glacier ice, in persisting in the narrow trough south of Vasseaux Lake dammed the meltwater north of it. In the lake north of the dam terrace masses were built out over the margins of wasting stagnant ice. Wastage of ice at the dam permitted the drainage to return to its former channel along the depression floor. The silt now occurs brokenly along the trough and is widest at the mouths of tributary streams; a maximum width of 4 miles of silt along the Okanagan Lake is attained at Kelowna; farther north it completely fills the depression bottom and is wider. Over much of the length of the depression the terraces or "benches" are narrow and interrupted by rocky outcrops. The terrace surfaces are usually smooth and dip moderately towards the valley axes. For the most part the silt consists of feldspathic rock flour and because of their creamy white colour were termed by G. M. Dawson, "the white silts." Sometimes the terrace deposits are sands and gravels. Around Rutland, for example, an important soil series consists of shallow sandy loam verging on glacial till.

While the white silts constitute the economically most important source of arable land in the Okanagan, soils almost directly derived from a fairly stone-free till obtain over appreciable areas north of Kelowna and in the south around Oliver. Recent fans, built by turbulent streams from the valley shoulders, sometimes of coarse gravel and sometimes of fine reworked terrace silts, occur irregularly along the valley bottom.

The area in the Okanagan depression having a topography suitable for arable agriculture is probably less than 400,000 acres. Only the Lower Fraser Valley rivals the area in agricultural importance. At present something over 50,000 acres, mainly white silts, are under irrigation in the Okanagan Valley. In addition there are considerable acreages of groundwater soils, needing no irrigation, and dry farmed soils. Except for a few groundwater types the arable soils are mainly zonal pedocals. There is a strong altitudinal and latitudinal zonation to be observed in the profiles along the depression (36). At low elevations and in the south, under physiologically dry conditions, brown soils are developed; at higher elevations and latitudes dark brown and black pedocals and a succession of intermontane podsolic soils are recognized. Before settlement much of the land classed as arable was in native bunchgrass; some was in montane forest (28).

(d) The West Okanagan Highland and Similkameen Valley

The West Okanagan Highland parallels the Okanagan Depression for 150 miles. It is 20 to 30 miles wide and summits of 6500 feet are noted in the south and 5000 feet in the north. The upland surface is generally well preserved. In the north, however, a series of "through" valleys related to those of the northern Okanagan depression, occupied by the Shuswap and Salmon Rivers, Chase and Monte Creeks, and Sicamous and Adams Lakes, dissect the highland in nearly rectangular pattern. Most of the agriculturally useful valleys are steep-sided and flat-bottomed at elevations of from 1500 to 2500 feet and are often filled with terrace sediments of fairly fine texture. The agricultural area, adjacent as it is to large areas of sheep and cattle range on the upland surface, is used primarily for hay production. The total arable acreage must exceed 20,000 acres; an appreciable amount is under irrigation. The acreage is scattered, however, but where valleys meet, arable areas 3 miles or more across, as at Westwold, may obtain.

While most of the West Okanagan Highland is too high for arable agriculture it provides summer grazing for range livestock and water storage for irrigation. And in the south the Highland is again dissected deeply by two through valleys, the Trout Creek Valley, with little arable land, and the Similkameen River Valley. The antecedent Similkameen River crosses the highland north of the 49th parallel in a deep narrow trench 35 miles long and 5000 feet deep. From Hedley to Keremeos, except at the junction of the Ashnola River, the bottom seldom exceeds 4000 feet in width but from Keremeos to the American border, in a few places, it exceeds 15,000 feet.

About 30,000 acres of land with a topography suitable for agriculture are found in the bottom; more than 3000 of these acres are under irrigation. Narrow terraces line the valley sides to 300 feet above river level. Most of the arable soils are the brown pedocals of the terraces or azonal ground-water soils of the valley bottom. Considerable areas of open grazing land, much of it steep and rough, lie adjacent to the Similkameen bottomland (49).

(a) The Princeton-Nicola-Kamloops Depression

The Princeton-Kamloops Depression, a trough of some definiteness, developed in Tertiary times, and extending from a point close to the American border south of Princeton, north for 150 miles to Kamloops, is only 20 to 30 miles wide. The depression is drained successively by streams which only run for a short distance along its axis, the Similkameen, the Nicola and the Thompson. Lakes are formed in nearly all parts of the depression; two, Nicola and Kamloops Lakes, are over ten miles in length. At least three basins, probably initiated in the late Tertiary, are recognizable along the depression; one centers around Princeton (2500 ft.) in the south, another around Merritt and another around Kamloops. "Soft" rocks of Carboniferous, Cretaceous and Tertiary ages are associated with each basin, a contributing factor no doubt for the more or less subdued local basin topography. In each basin, as Matthews (47) has described, seried lakes formed in late Pleistocene times as melting ice successively, dammed one narrow basin outlet or another. Associated with the lakes long since gone, were tremendous unconsolidated deposits in the form of

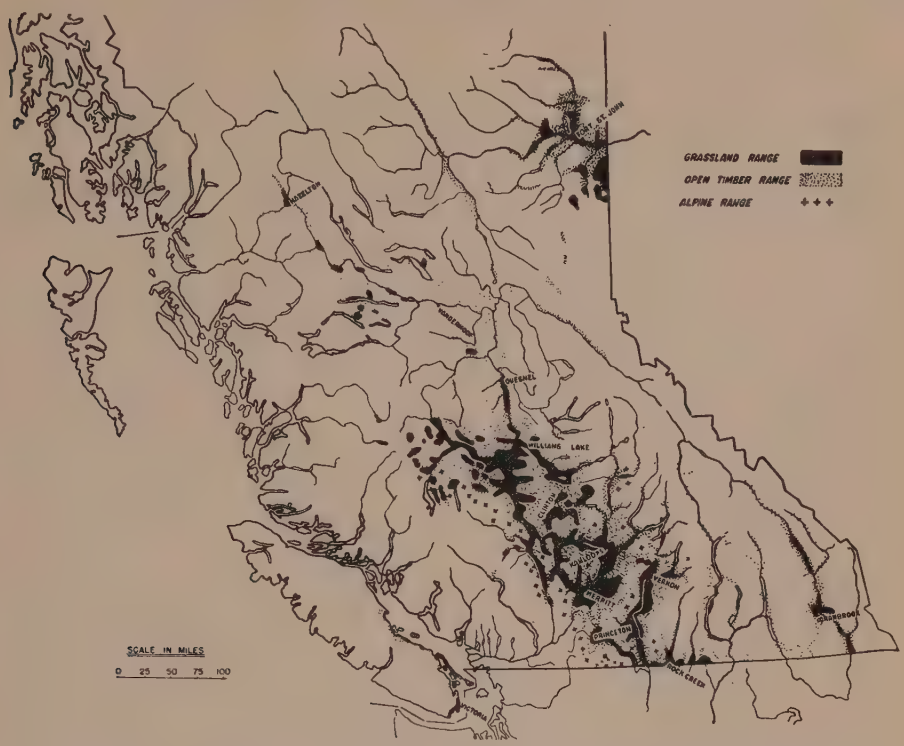

FIGURE 9. Livestock in British Columbia are ranged largely over the interior belt of plateaux: parts, also, of the coastal trench, southern Rocky Mountain Trench and Peace River plains support a limited range industry.

abandoned fans, flood plains, stream channels and terraces. In the basins large areas of relatively stone-free till exist. Associated with the basins are some of the largest areas of open grassland of good topography in the province. Soil zones in the area are closely related to altitude and aspect and are similar to those in the Okanagan.

The Princeton basin is the highest and smallest of the three basins along the depression. The agricultural usefulness centers around a sharply rolling native grassland of 110,000 acres and extensive timber and alpine range. A limited arable agriculture, some irrigated, is found on the 30,000 acres of arable terrace and alluvium.

The Nicola Basin, somewhat lower in elevation, also supports a grazing economy associated with one of the largest areas of open grassland in the province. An estimated 50,000 acres of land in the basin is capable of cultivation; 500,000 acres is in open grassland (49).

The largest basin, the Kamloops basin, has the lowest elevation (1200 feet) and the roughest topography. Its limits are difficult to define. One major river, the Thompson, has cut a deep transverse trench across the basin and the North Thompson, flowing perhaps as a continuation of the Princeton-Kamloops depression, enters the trench from the north. There are in the basin some 40,000 acres of cultivatable land and some 150,000 acres of open grazing land (18, 60, 63).

(f) The Western Highlands

The Western Highlands (11) lying between the Princeton-Kamloops depression and the eastern margin of the Coast Range extend northward from Coquilhalla Pass to obtain a maximum width of 70 miles at latitude 51°. Generally speaking the upland surface is well preserved in spite of high elevations (maximum 7500 feet). The deep narrow V-shaped gorges of the Nicola, Thompson and Fraser Rivers penetrate the Highlands. Apart from the limited grazing lands on the upland surface the agriculturally useful lands in this section are confined to these gorges. Again terraces of late Pleistocene age cling to the steep valley walls above river level and upon their surfaces there is some arable land. Irrigated haylands are found on scattered benchland, seldom over 1000 yards wide along the Nicola, the Thompson and along the Fraser as far south as Boston Bar. At Lytton, where the Thompson and Fraser are confluent and at Lillooet 40 miles north on the Fraser, the terraces support an intensive agriculture on several thousand arable acres. Also in the Highlands are the wild hay meadows of the Coldwater, Tulameen and other valleys.

(g) The Cariboo-Chilcotin Plateaux

The physiographic division of the remainder of the Interior Belt of Plateaux in Central and North Central British Columbia presents some difficulty and until such time as more information is available it seems best to treat that part of this belt lying north of the Thompson River as a unit. A tentative recognition of the two divisions—the Cariboo-Chilcotin and the Nechako Plateaux—has long been maintained (61). The division rests primarily upon a poorly defined "East-West" highland north of the Chilcotin River and south of the Nechako River—made up of the Telegraph Range and other ranges to the west—with summit elevations rarely over 5000 feet. The highland rises some 2000 feet above the general elevation of the Nechako plateau but only 500 to 1000 feet above the Cariboo-Chilcotin plateau.

From rounded summits of from 5000 to 6000 feet North and West of the Thompson and North Thompson Rivers, the plateau surface trends strongly north-westward widening perceptibly at latitude 52° as the Coast Range "swings" with a strongly westerly component. In latitude 54°, in the valley of the Fraser near Prince George the plateau surface merges with the floor of the Rocky Mountain Trench. Drainage, except for the western fringes of the surface, is by the Fraser River which, in its southward flow, cuts diagonally across the plateau surface. At Prince George the valley of the Fraser, while narrow, is but a few hundred feet below the general upland surface but as it flows southward the course becomes more canyon-like and below Gang Ranch where it begins to parallel the Coast Ranges the plateau surface is 2000 feet above river level. Tributary streams cross the plateau from the east and west; as for the major streams, the Chilcotin, Blackwater, Quesnel and Nechako, their canyon or valley development closely parallels that of the Fraser. Smaller tributaries, such as the San Juan River, however, often cross the plateau surface on a gentle gradient to plunge steeply to the major streams near their confluence.

Viewed broadly, the plateaux presents a comparatively uniform surface, broken chiefly by the deep cuts of the major streams and in general reflects the undisturbed character of the Tertiary volcanics which underlie

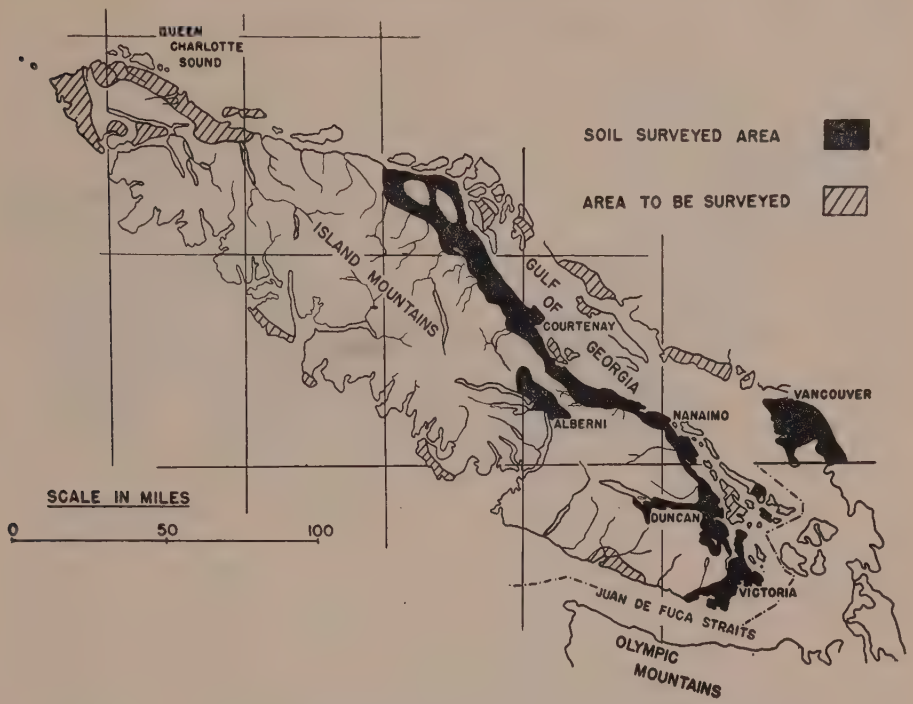

FIGURE 10. Areas on Vancouver Island within which arable land may be found.

70 per cent of the area. A study of the micro-relief, however, reveals the presence of large numbers of moraine dammed lakes and sloughs, drumlins, eskers, abandoned stream channels and alluvial fans. In some places glacial till is thick and over large areas it is thin. In short, the effects of the Pleistocene ice in scouring, depositing, laking and washing are much in evidence over the plateau surface.

In the Cariboo and Chilcotin, elevations are comparatively high over the plateau surface—3000 to 4000 feet (Figure 3). Most of the upland, especially at the higher elevations, is lightly forested (less than 5000 M.B.M.) and is lake dotted. At lower elevations, close to the major drainage channels, open grasslands occur. Terraces with gentle surface gradients and steep fronts occur as prominent features of the major valleys such as the Fraser and Chilcotin. High elevation, rough microtopography and the great development of light or rocky soils combine to limit agricultural land. Arable areas are scattered and confined chiefly to the major valleys, terraces and grasslands. Upland elevations are generally too high for successful farming. Some 70,000 acres are under cultivation; much of it is irrigated. On the west bank of the Fraser there are some 700,000 acres of open grazing land, on the east bank, 500,000 acres. Inasmuch as ranching is the principal agricultural enterprise, arable land is devoted largely to hay production. Natural meadows, often of considerable size, are abundant in nearly all parts of the upland. Brown soils, characterizing the areas of low grassland, are found only at elevations below 2000 feet in the major trenches. Shallow black soils characterize the more abundant upper grassland on the plateau surface. Grey-wooded soils characterize much of the forested area.

(h) The Nechako Plateaux

In the late Pleistocene, ice undoubtedly lay in the valley of the Fraser at points south of Prince George, such as Soda Creek and Jesmond long after it had departed from the upland surface of the Nechako plateau. A great glacial lake or lakes must have extended from the ice dams, certainly from Soda Creek northwards up the Fraser almost to present day Peace River drainage and far west to the present site of Fort Fraser to fill old Tertiary basins. An almost continuous lake or chain of lakes over two hundred miles in length may have been created. To-day the presence of the late Pleistocene laking is recorded in the great thicknesses of lacustrine quasi "white silts" spreading broadly over the Nechako and Upper Fraser Basin. Adjacent to and sometimes mingled with the finer lacustrine materials are broad plains of gravel, sand and till, especially to the north. While ice blocked the present drainage, the overflow from the lakes must have taken place to the northward into the Rocky Mountain Trench and Peace River drainage. Well developed lakeshore features are found at elevations up to 2700 feet. The principal surface varies from 2000 feet to 2400 feet. As the ice block to the south melted by stages, drainage was resumed down the Fraser River Valley. The streams of to-day, the Nechako, Cottonwood and Fraser along with their tributaries, cut rapidly through the soft strata, break the lacustrine surface with sharp canyons 100 to 500 feet in depth. The uniformity of the surface is yet largely retained, however, and to-day constitutes one of the largest topographically uniform areas in British Columbia (3, 4, 37).

The Nechako basin and plateau extends in long fingers northward beyond Stuart Lake and well into the mountains of Omineca System; it merges imperceptibly over a low pass (Summit L.) with the Peace River drainage in the Rocky Mountain Trench. The surface breaks sharply with the outlines of the Columbian Mountain system and the Telegraph Range in the southeast and gradually with the rolling hills of the Lake Country (Francois and Ootsa Lakes) to the south. The broad Bulkley Valley and Babine Valley (lake filled) to the northwest are separated from the basin by low passes.

In North Central British Columbia agriculturally useful lands are also found in the Bulkley Valley and in the lake country areas adjacent to the Nechako Basin but hardly part of it. The Bulkley Valley lies between two ranges flanking the Coast Range, the Bulkley and Babine Mountains and is probably, in part at least, structural in origin. The valley floor, of moderate relief rarely totalling 1000 feet, presents a varied array of tills, lacustrine bottoms, terraces, alluvial fans, eskers and moraines. An appreciable fraction of the bottom is composed of deposit of sufficient uniformity and fineness to be agriculturally useful.

Subdued topography is also associated with the lower slopes and inter-lake valleys of the lake country. Ice and water have etched long narrow fiord-like valleys across the subdued surface of the Tertiary lavas.

Over 1,500,000 acres of arable land have been surveyed in the Nechako Basin, Bulkley Valley and adjacent lake country. Most of it is lightly timbered and most of it is characterized by grey-wooded podsols. Some shallow black grassland soils have developed, principally west of Vanderhoof

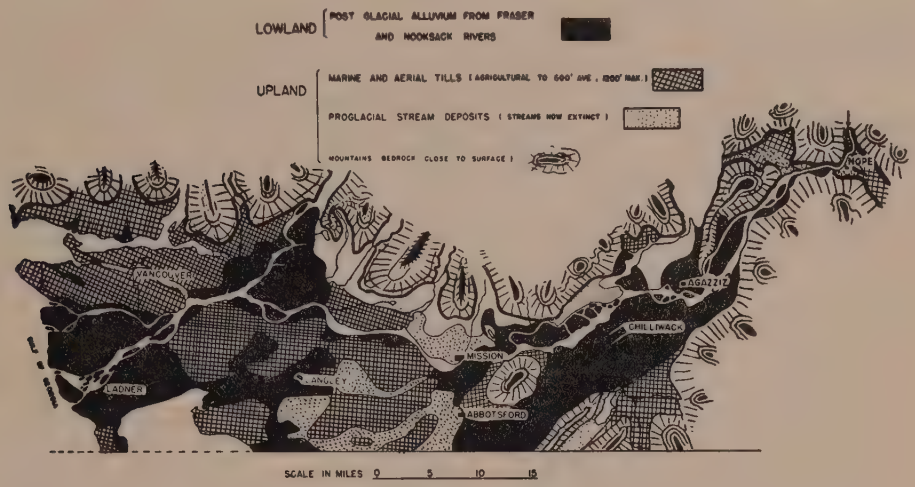

FIGURE 11. The lower Fraser Valley: most of the area shown is agriculturally useful.

in the Bulkley Valley. Only some 300,000 acres of open grazing land, widely scattered, is estimated for the area (21, 49).

(i) The Interior Plateaux in Northern British Columbia

While the Interior Plateaux Belt finds a counterpart north of the Nechako Basin (34, 77, 78) lands even for gardens are very limited. Some tundra-like grassland is found on land on low relief at elevations of 3500 to 4000 feet in the lee of the Coast Range. Around Atlin, apparently, on soils of lacustrine origin laid down in one of the great chain of late Pleistocene lakes which extended from British Columbia far into the Yukon, a few hundred acres of arable land have been developed. Terraces above the town of Telegraph Creek on the Stikine and Tanzilla Rivers may have a limited agricultural usefulness.

THE COLUMBIAN MOUNTAINS

The Columbian Mountains rise from the Interior Plateaux on the west and extend to the Rocky Mountain trench on the east. The southern limits of the system, across the International Boundary, are hard to define. On the north, the system fades out about the latitude of Prince George into a broad plateau where the Interior veldt and the Rocky Mountain trench are confluent. While others (17) have properly subdivided the Columbian Mountains, there is a certain unity of topographic form throughout the system. The ranges are characterized by either flat topped summits or horns which may surpass elevations of 10,000 feet, in several sections. The effects of the Pleistocene and recent glaciation are shown by numerous cirques, tarns, and deep U-shaped valleys which often show the over-deepened long profiles of valley glaciation. An outstanding character of parts of the system is the development of low passes between parallel valleys often large out of all proportion to the streams which occupy them. The rocks of the system are principally highly metamorphosed sedimentaries and volcanics, probably of Pre-Cambrian Era, intermixed with considerable areas of granitic, batholithic elements (27).

(a) The Grand Forks Area

Limited areas of agricultural land are found in some of the great longitudinal and transverse valleys of the system. On the west, in valleys occupied by the Kettle River especially at Grand Forks there are pro-glacial alluvium and terrace soils under irrigation. Limited areas of open and semi-open valley sides and bottom are used for cattle range and hay meadow. Around Grand Forks (elevation 1800 ft.) is found the largest single acreage of arable land in the West Kootenay with about 20,000 acres at present under intensive cultivation.

(b) The Columbian (Arrow Lakes) Trench

The Columbian Trench (Figure 1) striking about north and south, from the Rocky Mountain trench in the north to the lava plains of Washington State in the south, is occupied by the Columbia River and the Arrow Lakes. The trench is seldom more than one or two miles wide and is bounded throughout by high mountains. It is lake-filled for more than one-third of its length; bottom elevations run around 1500 feet. Arable land is found in interrupted pro-glacial alluvium and terrace from Revelstoke to Arrowhead and Sidmouth at the northern end of the Arrow Lakes for a distance of 30 miles. Scattered narrow terraces, usually only a few hundred yards wide, cling to the steep walls along the Arrow Lakes and support some orchards. In the vicinity of Castlegar where the valleys of the Columbia and Kootenay meet terrace and alluvium permit the settlement of a few thousands of acres.

(c) The Purcell (Kootenay) Trench

The eastern portion of the Columbian mountains is again partitioned by a fairly well defined trench, the Purcell (or Kootenay) trench. This feature is initiated in the north by the valley of the Beaver River which debouches into the Columbia River in the Rocky Mountain trench. The trench is occupied successively by the Duncan River, Kootenay Lake and Kootenay River (51). Several thousand acres of arable land (the Lardeau area) some distance from the principal transportation systems and largely undeveloped, are found along Trout and Duncan Lakes and at Argenta at the northern end of Kootenay Lake. Narrow Benches at Kaslo and other scattered points along Kootenay Lake support an arable agriculture. At Creston, elevation 1700 feet, at the southern end of Kootenay Lake are 25,000 acres of alluvium (19,500 acres reclaimed) and 5000 acres of intensively farmed terrace. Many other narrow valleys in the Columbian system have small and scattered acreages of arable land; of these the Slocan valley, largely lake-filled, located between the Purcell and Columbia trenches and paralleled by them, the Pend Oreille, Salmo and Beaver valleys, and the Seymour valley at the northern end of a fiord arm of Shuswap Lake should be mentioned.

(d) The North Thompson Trench

Important acreages of arable and grazing land are in use along the narrow valley of the North Thompson River for 100 miles from Kamloops to Vavenby along the main line of the Canadian National Railways. The lands, however, are confined to narrow terraces and alluvial bottom which are frequently broken by rocky outcrops.

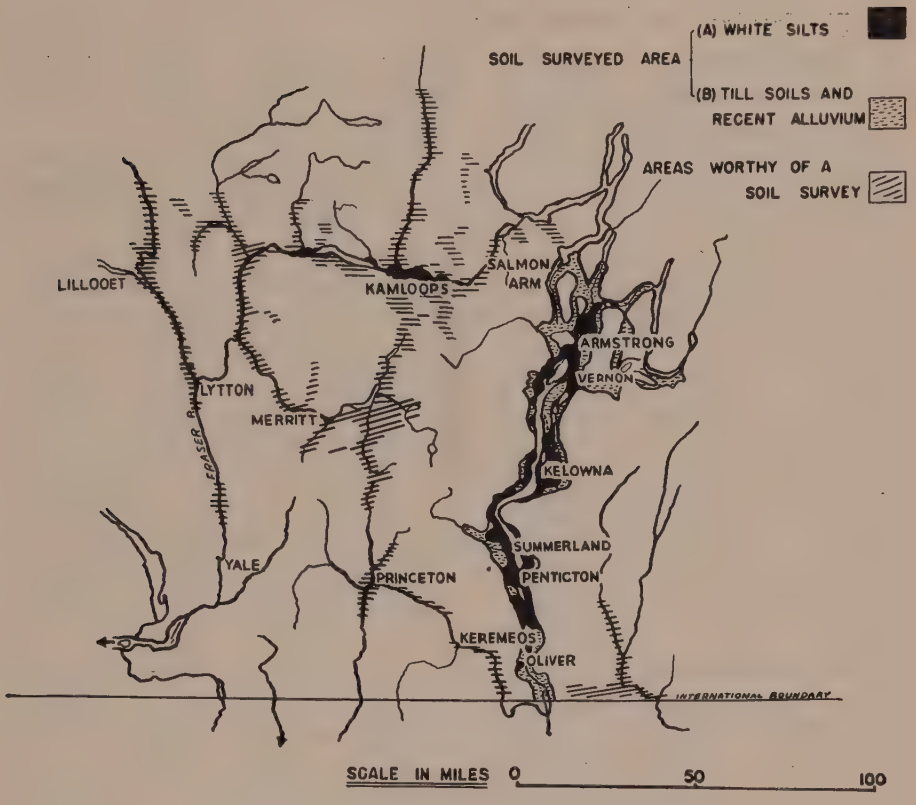

FIGURE 12. The Okanagan-Thompson Valleys.

THE ROCKY MOUNTAIN TRENCH

From Flathead Lake in Montana to the Liard River and beyond, a distance of more than 900 miles, there runs a narrow, wonderfully straight depression lying between the Rocky Mountains on the east and the rest of the Cordillera on the west, termed the Rocky Mountain trench. Unique among the physiographic features (59, 60) of the globe for its persistence the trench is in turn occupied by the headwaters of the Flathead, Kootenay, Columbia, Canoe, Fraser, Parsnip, Finlay and Kechika Rivers. The trench bottom over most of its length is only one or two miles wide but in places, notably in the south around Cranbrook and in the north around Finlay Forks, it may exceed ten miles in width over considerable distances. Around Cranbrook the valley bottom elevations may drop slightly below 3000 feet, but at Finlay Forks elevations average 1000 feet lower. East of the trench the west margin of the Rocky Mountains rises abruptly, 6000 to 8000 feet in a wall of well stratified rock. Bold ridges often 8000 feet high, with deeply incised valleys between, rise in a continuous array along the western side of trench to present a striking contrast between the two sides of the trench over much of its length.

(a) The Cranbrook-Windermere Area

Two agricultural areas worthy of note, the Windermere Valley and the Cranbrook district, are developed in the trench between Golden and the International Boundary, a distance of 175 miles. The general relief of the broad bottom in this section appears to be broken only by a few foothills. Closer examination reveals a surface broken frequently by conspicuous moraines, kettles, eskers, and terraces of silts, sands and gravels. "During the Pleistocene the area was covered by a continental ice sheet which, as it disappeared, resulted in a stage of alpine glaciation." During both stages acute erosion by ice took place only at high elevations (8, 53, 53). The final disappearance of the ice in this part of the trench took place in stagnation. In recent times there has been much reworking of the glacial materials. Good agricultural soils, then, are scattered. While they are topographically suitable for agriculture, many terrace soils are coarse and excessively well drained. Conversely, poor drainage characterizes much bottom land and without reclamation it is useful only for wild hay production. The southern part of the trench supports an open vegetation and a small range industry has developed. On what appear to be loessial soils around Cranbrook, a dry farming agriculture has developed. More extensive pro-glacial laking around Windermere, has resulted in fairly extensive development of terraces and bottomlands of white silts which support a mixed agriculture. The terraces are least developed at 2700, 2800 and 3000 feet on both sides of a central depression largely lake-filled about three-quarters of a mile wide (67).

(b) The McBride Area

Hay meadows are common along the Fraser River as it flows in the Rocky Mountain trench towards Prince George. At McBride, 150 miles east of Prince George, several thousand acres of raised delta and alluvio-lacustrine soils are used for mixed farming.

(c) The Finlay-Parsnip Area

Terraced lacustrine materials of fairly fine character are reported to fill a very large area of the Rocky Mountain trench occupied by the lower reaches of the Finlay and Parsnip Rivers (1, 75). The Peace River drainage was apparently resumed in Pleistocene times before the Fraser drainage and silt-laden waters from Central British Columbia no doubt flowed into the Rocky Mountain trench. It would appear, too, that considerable laking occurred in the valleys of the Finlay and Parsnip due to ice damming in the upper Rocky Mountain reaches of the Peace River (6). Possibly for a time the spillway of the pro-glacial lake was Pine River Pass. In any event, there are several hundred thousand acres of fairly well sorted lacustrine soils in the Rocky Mountain trench at this latitude, some of which may become agricultural if difficulties of transportation and shortness of growing season are overcome.

THE ROCKY MOUNTAINS

The Canadian Rocky Mountains "are bounded on the west by the Rocky Mountain trench and on the east by the foothills and the Great Plains (72)." Originating in Montana (or perhaps, some might believe, farther south) the range persists in essential unity north to the Liard Valley. The chain presents few "breaks" along its length and few passes are below 5000 feet in elevation; in the vicinity of the Peace River, however, where the range is narrow (20 miles) the summits and passes are lower; Peace River Pass is but 1500 feet, Pine Pass, not quite 3000 feet. North of the Peace River summit elevations of over 9000 feet have been established; south of the Peace River lies Mount Robson (elevation 12,972 ft.), the highest peak in the Canadian Rockies, and many peaks over 10,000 feet in elevation are found in the range to the border. In aspect the range is quite different to the rest of the Cordillera in British Columbia which is largely vegetated and constituted of plutonics and highly metamorphosed sedimentary, volcanic rocks. In the Rockies "rugged peaks and precipices, gorges and valleys have been carved by erosion out of sedimentary formations of blue-grey limestone, dark shale, buff sandstone and quartzite. Clean-cut surfaces expose mountain folding and faulting so well that pressure from the west is clearly demonstrated as the origin of the structure" (82).

The Canadian Rocky Mountains will not support agricultural pursuits. They are quite unsuited for domesticated grazing animals such as may be found in the Swiss Alps. Certain grazing and browsing areas, however, are largely used by big game and a few mountain pastures in the south are used by range livestock.

THE TRAMONTANE PLAINS

The Tramontane Plains of northeastern British Columbia make up 10 per cent of the acreage of the province (1). Structurally and geologically they occupy a position similar to the plains of Alberta and are integral parts of the Great Plains region, the heartland of the North American continent (56, 69, 70).

When compared with other parts of the political province the tramontane area is conspicuous in the uniformity of its surface. However, physiographic subdivisions based on topographic and stratigraphic considerations may be recognized.

(a) The Foothills Section

A foothills section, fifteen to twenty miles wide, along the lee of the Rocky Mountains, consists of hills whose flat-topped concordant surfaces slope easily to the east. Bedrock is, almost entirely, gently folded Cretaceous shale and sandstone (6, 45). In the vicinity of the Peace River canyon maximum relief is from 1500 feet to 5000 feet above the sea and in the vicinity of the Nelson and Liard Rivers very little less.

FIGURE 13. North Central British Columbia and Peace River areas showing areas within which arable lands are located.

Agriculturally useful land is found in the foothills section only on the terraces which border the Peace and Liard Rivers. Some of the terraces, as found around Hudson Hope on the Peace River, are broad and continuous for several miles; they are usually well preserved up to elevations over 500 feet above the river. A limited agriculture has been developed on a few terraces near Hudson Hope and Gold Bar.

(b) The Peace and Nelson Basins

Two great basins, 500 to 1000 feet below the mean level, may be recognized in the tramontane area of northeastern British Columbia, the Peace River basin in the south and the Nelson basin in the north. Agricultural interest centers in the broad lands which slope gently towards the major streams, the Peace, the Nelson and a few of their tributaries (56).

The principal agricultural soils of the Peace River basin in British Columbia are found at elevations from 1800 feet to 2400 feet. Maximum elevation for agricultural lands may be liberally placed at 3000 feet. The lower elevations, around 1000 feet, in the Nelson basin compensate somewhat for its more northerly location and some of the well drained benches with southerly exposure close to the major streams, the Musqua, Prophet and Nelson Rivers may eventually be useful agriculturally. Underlying the basins are sedimentary rocks of Cretaceous age which thicken from east to west (2); quaternary gravels, silts and clay mantle these. In the Peace basin and probably also in the Nelson basin pro-glacial lakes developed in Pleistocene time between the Keewatin ice front on the east and the foothills on the west. Some glacio-fluvial sediments in and around the basins

came from the Shield rocks to the east. The lacustrine, outwash, and flood plain origins of the soils are much in evidence but their genesis has not received careful study. Limited areas of shallow black and degraded black soils occur in the Peace basin. Some of these at Pouce Coupe, Dawson Creek and Fort St. John, prior to settlement, were in open grassland and parkland. By far the greater area is characterized by grey wooded podsols (23).

(c) The River Valleys

The Peace River and its tributaries in British Columbia are deeply entrenched in steep walled valleys 600 or more feet below the mean basin level (56). The deep valleys, a recent erosion feature, constitute important barriers to easy development of the agricultural soils of the basin. Underdrainage, too, is excessive in the lighter soils near the breaks high above the rivers and water shortage exists in places. In the Fort Nelson area the major streams are in places entrenched 400 feet. Drainage, however, is sufficiently impaired to create muskeg conditions over considerable areas.

(d) The Uplands

Semi-continuous uplands, flat-topped, generally covered with relatively stone-free till, make up a large fraction of the lands of the tramontane area. Some of the elevations dividing the Peace and Nelson basins approach 4000 feet. Tertiary feature remnants are probably represented in the upland surface (69, 71).

DISCUSSION

Some principal impressions to be gained from the foregoing account of the provincial physiography are that British Columbia presents an extremely rough, predominantly mountainous aspect, that there is a "limited" amount of arable land, and that the arable land is, in the main, remarkably diffuse. Daly (17) writing of the southern border lands of the province, has said that no other mountains both so continuously rough and so wide exist in the world. No verbal description can quite convey the picture of the uneven land surface. Good physiographic maps assist materially (68, 78). Aerial photos of the political province which also may be used to gain suitable impressions are now available in excellent libraries (76, 78). Only a very few representative air photos could be included in this paper (Figures 2-5).

Elevation above the sea is of utmost importance in appraising the arable lands of British Columbia. Nearly all tillable soils will be below the 3000 feet contour (Figure 6). Certainly the growing season is so short at higher elevations north of latitude 52° that the development of little but gardens is permitted. Admittedly at Rose Hill, Alkali Lake and Bridesville, all points on the Interior Plateau surface, dry farming is practised in a limited way at elevations above 3000 feet. Reference to Figure 6 which shows the pattern of the distribution of lands below this contour, about 30 per cent of the provincial total, is an important step in showing the extent and distribution of arable lands.

Figure 8 shows areas of the province which are topographically uniform enough to permit an arable agriculture. The pattern is essentially that by Whitford and Craig (68), with modifications, and delimits about 10 per

cent of the total acreage of the province. Lands outlined, of course, are not wholly arable but have a uniform macrotopography and elevations and latitudes which will generally permit at least cereal culture. Parts of these areas, however, will possess poorly drained soils, porous members, non-irrigable soils or a microtopography too rough for the plough. Principal agricultural areas, it also may be seen, are associated with the non-mountainous physiographic divisions, the Coastal trench, the Interior belt of plateaux, the Rocky Mountain trench, and the Tramontane Plains.

Range lands are not limited by a 3000 feet contour; also grassland too rough for the plough and timbered lands may be used by range sheep and cattle. Figure 9 is an attempt to show the distribution and character of the range lands of the province. Grassland range is found at all elevations up to 4000 feet, timber range to 6000 feet, and alpine range to 7500 feet depending on latitude and exposure. Most of the range land, it may be noted, is associated with the Interior belt of plateaux; limited range is found in the southern Rocky Mountain trench, in the Kootenay and Peace River Districts and on Southern Vancouver Island.

Maps (Figures 10, 11, 12, 13) of the four principal agricultural areas of British Columbia show some details of physiographic and distributional nature not shown in Figure 3. It seemed worthwhile to emphasize in Figure 11 the pattern and genesis of the lowland and upland soils of the Lower Fraser Valley. Planning for the best use of these important soils must take careful account of these features, correlated as they are with moisture supply, drainage, and productivity. On the map of the Okanagan-Thompson area (Figure 12) it seemed desirable to emphasize the distribution of the white silts to which previous reference has been made for it is on these that the valuable tree fruit industry has developed.

Many attempts have been made to assess the total acreage of arable and range land in British Columbia (1, 68, 75). One of the most recent and most comprehensive is that of the forester, Mulholland (49) who places the estimate at 4,250,000 acres or 2 per cent of the total provincial area. An additional 2 per cent or 4,700,000 acres are in open grassland and park suitable for range. No estimates are given for timber range but this is a little consequence, since lack of open grassland is distinctly limiting the greater use of this range class. Out of a total of 234,400,000 acres in the province, Mulholland finds 154,700,000 acres or 66 per cent unsuitable for forestry or agriculture.

One can readily see that disposition of the arable lands of British Columbia on physiographic bases and on total acreage does not compare favourably with their disposition in the Prairie Provinces and Eastern Canada. Valuable though the physiographic approach may be in showing the distribution, size and shape, and in indicating the nature of arable lands, non-physiographic features should, of course, be considered also in assessing their value. Some of the lands enjoy Canada's more favourable climates. All bear relationships to large consuming populations in south-western British Columbia whose agricultural needs are scarcely met by the lands within the province. Important mining, fishing, forestry and manufacturing industries are related to the arable lands. Nearly all arable lands, too, are closely associated with the major lines of transportation.

Another impression to be gained from a physiographic study of the agricultural areas of British Columbia is the very great importance of the Pleistocene and post-Pleistocene geology in the soil genesis. Pleistocene ice covered nearly all of the province and profoundly modified its topography. Virtually no arable soils have developed *in situ*. Most soil profile development has occurred within the last 20,000 years (73). Great pro-glacial lakes with their associated terraces and bottom silts played a major role in the deposition of arable soils. Glacial streams, now much reduced or no longer extant, resorted till and loess to build fans and deltas on which farms may be located to-day. Alluvium deposited in deep waters along the coast and subsequently elevated with the rising post-Pleistocene shoreline has yielded plowlands on Vancouver Island and the Lower Fraser Valley. More attention by geologists and others to the genesis of the superficial deposits over the province is warranted.

While the importance of physiographic controls has been emphasized occasionally for British Columbia, few persons have yet grasped their profound importance in meaningful descriptions of the provincial soil, climate and biota. Our particular interest in this paper has been to relate the agricultural lands to the physiographic features; our interest has aimed, not at finely delimiting our arable acres and ranges, but at designating their probable location and emphasizing their distribution—their macro characteristics. The Dominion-Provincial Soil Surveys and the Provincial Land Utilization Surveys will provide, before many years have passed, a more comprehensive description of the agricultural soils. Few, however, will deny the need for re-emphasis (1, 5, 12, 20, 26, 29, 43, 51, 66, 68, 74, 75) of physiographic features at this time when much energy is being devoted to proper land use, and conservation and when attempts are being made at more comprehensive accounts of our climate, and biota. Following the physiographic approach, appraisal of our lands and farm problems will, we hope, be made easier for the novice in British Columbia agriculture.

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EQUINE PREGNANCY DIAGNOSIS BY BIOLOGICAL AND CHEMICAL TECHNIQUES[1]

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INTRODUCTION

Equine pregnancy has been determined by several biological and chemical methods, the former depending on the early presence of gonadotropin in the blood, the latter depending on the later appearance of estrogen in the urine. Cole and Hart (1), using both the ovarian weight and the vaginal smear of the immature rat as criteria of pregnancy, report that blood specimens from mares under test should be taken between the 45th and 120th days of pregnancy. Mayer (2), applying the ovarian weight test, considers that the optimum time for testing blood serum is between the 50th and 90th days. A chemical procedure developed by Cuboni (3) depends on the presence of estrogen in pregnant mare's urine. Most workers consider this test to be applicable after the 120th day of pregnancy.

Both biological and chemical methods have been applied to establish the percentage of successful matings in a series of one hundred and nineteen mares. Circumstances prevented the testing of all the mares by both methods, as planned, but sufficient information has been obtained for a comparison of the relative reliability of the two methods. Foaling data provided confirmation of the tests. The specimens for examination were selected at the optimum stage of pregnancy for each test.

PROCEDURE FOR BIOLOGICAL TEST

Blood from the jugular vein was first allowed to clot and then was chilled overnight. The serum was decanted into sterile bottles containing merthiolate in such an amount that the preservative concentration was 1-10,000. This precaution was taken because some of the blood specimens were collected at a considerable distance from the laboratory. To ensure that the presence of merthiolate would have no effect on the test a preliminary trial was made on a known sample of pregnancy serum using aliquots with and without preservative.

Rats from 21-23 days of age were injected subcutaneously with 2 ml. of the serum. Two test rats and one control were used for each serum specimen. The rats were sacrificed after 96 hours and a 50 per cent increase in ovarian weight was considered to be a positive reaction. The presence of cornified cells in vaginal smears confirmed the positive diagnosis in every case.

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PROCEDURE FOR CHEMICAL TEST

Urine samples were received in 2 oz. bottles containing 2 ml. toluol to inhibit bacterial decomposition. The test for pregnancy, as outlined, was essentially that of Cuboni (3) with slight modifications by Cole and Hart (1).

Acidify 5 ml. of urine with 1 ml. of concentrated hydrochloric acid. Place in a boiling water bath for 10 minutes, cool and extract with 6 ml. of benzol. Dry 3 ml. of this extract at 60° to 80° C. Add 4 ml. of concentrated sulphuric acid to the residue and warm in a water bath to 70° to 80° C. Read in 10 minutes by reflected light.

To ensure that the green fluorescence indicative of a positive response was due to estrogen alone, 1 ml. of water was added to eliminate any green colour due to the presence of sterols. Negative specimens under this treatment are reddish brown.

RESULTS

The survey for pregnancy comprised one hundred and nineteen mares. A total of ninety-six samples of urine and forty-seven samples of blood were obtained. As twenty-four mares were diagnosed by both biological and chemical methods and since foaling records were available it was possible to assess the relative reliability of the two methods employed for diagnosis. Comparative data for both methods are shown in Table 1.

It may be noted in Table 1 that the biological and chemical techniques gave 91.5 and 92.7 per cent correct diagnoses respectively. Mayer (2) suggests that the error in diagnosis based on serum examination need not be over 5 per cent while Cole and Hart (1) suggest the limit of 2 per cent. According to the latter authors the Cuboni test on urine may give 1-5 per cent false diagnoses. The comparatively large error reported in the present survey was due to the incorrect negative diagnosis of seven mares. It may be seen in Table 2 that four of these animals were examined by both methods.

TABLE 1.—A COMPARISON OF BIOLOGICAL AND CHEMICAL METHODS FOR EQUINE PREGNANCY DIAGNOSIS

Diagnosis	Biological (serum) test		Chemical (urine) test	
	Number of mares examined	Days pregnant	Number of mares examined	Days pregnant
Correct negative	36	62–127	72	137–251
Correct positive	7	59–106	17	127–271
Incorrect negative	4	65–85	7	166–215
Incorrect positive	0	—	0	—
Total	47		96	
Error in diagnosis	(%) 8.5		(%) 7.3	

Total number of mares examined, 119.

TABLE 2.—ERROR IN EQUINE PREGNANCY DIAGNOSIS

Biological (serum) test			Chemical (urine) test		
Horse No.	Interval (days)	Diagnosis	Interval (days)	Diagnosis	Foaling record
92	65	Negative	166	Negative	Foaled
95	85	Negative	166	Negative	Foaled
117	85	Negative	213	Negative	Foaled
96	85	Negative	215	Negative	Foaled
43			182	Negative	Foaled
27			198	Negative	Foaled
114			208	Negative	Foaled

The errors in diagnosis are not apparently related to the times at which the specimens were obtained. The collection times for both serum and urine fall well within the time interval for the other mares in the series which were correctly diagnosed. One possible explanation for such error might be that the hormone levels of these particular animals were too low at the time of collection to give a measurable reaction. Hormone levels in mares are known to be subject to wide variations.

A study of twenty-four mares which were tested by both methods shows that all mares, including the four which were incorrectly diagnosed, gave identical responses in each test. It would appear that the error is not inherent in the methods but rather it is due to some peculiarity of these particular horses.

SUMMARY

A pregnancy survey involving one hundred and nineteen mares was based on diagnosis by biological testing of serum or by chemical examination of urine. Some mares were tested by both methods. Collections were made at the optimum stage of pregnancy for each method and foaling records were used to determine the reliability of the methods.

All positive diagnoses were confirmed.

Incorrect negative diagnoses by biological and chemical methods were made in 8.5 and 7.3 per cent of the tests, respectively.

Mares which were examined by both methods gave identical responses for each test.

While the biological procedure provides an early diagnostic test the chemical procedure, because of its economy, simplicity and comparative reliability, is preferred for pregnancy confirmation.

ACKNOWLEDGMENT

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